

## Porcellidiidae of Australia (Harpacticoida, Copepoda).

### II. The Importance of the Male Antennule in Taxonomy

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**ABSTRACT.** Nine new species belonging to the Porcellidiidae are described from Queensland and New South Wales, Australia. Two new genera *Ravania* gen. nov., and *Synurus* gen. nov., have been erected to accommodate three new species from Queensland, *Ravania wellsi* sp. nov., *R. doliocauda* sp. nov., and *Synurus ctenocheirus* sp. nov. Two other new species, *Acutiramus bipunctatus* sp. nov., and *Kensakia australis* sp. nov., are also described from Queensland. Four new species are added to the New South Wales list, *Kushia spathoides* sp. nov., *Acutiramus edenensis* sp. nov., *A. cumulus* sp. nov., and *A. iwasakii* sp. nov. A Japanese species, *Clavigofera pacifica*, is recorded from NSW. This brings the total number of species known for the East coast of Australia to 30. The importance of the male antennule in taxonomy of the family is discussed.

**KEYWORDS:** Porcellidiidae, *Porcellidium*, *Ravania*, *Synurus*.

HARRIS, VERNON A. 2014. Porcellidiidae of Australia (Harpacticoida, Copepoda). II. The importance of the male antennule in taxonomy. *Records of the Australian Museum* 66(2): 111–166.

Twenty species of Porcellidiidae have been described from New South Wales and Victoria, but none from Queensland, Australia. They were placed in seven genera (*Porcellidium* and *Acutiramus*, Harris & Robertson (1994), *Tectacingulum*, *Murramia*, *Kioloaria* and *Brevifrons* Harris, (1994) and *Dilatatiocauda*, Harris (2002), however, Walker-Smith (2001) placed *Acutiramus*, *Murramia* and *Kioloaria* in *Porcellidium* on the grounds that they were not based on apomorphic characters. This confusion arose from the fact that the type species for *Porcellidium* had never been adequately described. The re-description of *Porcellidium viride* (see Harris, 2014) has enabled a definitive diagnosis to be given for the genus and the validity of all the proposed

genera to be reassessed. The species recorded from South Australia by Nicholls (1941) are not considered here because his descriptions are inaccurate and do not allow positive identification.

The present account describes five new species from Queensland. Two of these share many features with *Porcellidium ravanae* Thompson & Scott, 1903 which was re-described by Wells & Rao (1987). Some of their characters appear to be apomorphic. This excludes them from *Porcellidium* and so it is proposed to place them in a new genus, *Ravania* gen. nov. A third Queensland species resembles *Porcellidium unicus* Ummerkutty, 1970. They both share a number of apomorphic characters which exclude

them from *Porcellidium*. It is proposed that these animals are placed in a new genus, *Synurus* gen. nov. The genus *Acutiramus* is redefined and maintained to accommodate a new species from Queensland, *A. bipunctatus*, and three new species from NSW, *A. edenensis*, *A. cumulus* and *A. Iwasaki*. Two new species are described, *Kensakia australis* from Queensland and *Kushia spathoides* from NSW which belong to genera previously only known from Japan and Korea.

The Japanese species, *Clavigofera pacifica* Harris & Iwasaki, 1996, is recorded in Australia for the first time.

A survey of 50 Australian and Japanese species, for which detailed information about the structure of the male antennule is known, has shown that this appendage offers more useful taxonomic characters than any other part of the body. Not only do they show species specific characters that positively identify each species, but the overall configuration of shape, type and placement of setae and the shape, number and position of the coupling denticles is characteristic for each genus. Consequently the male antennule has far greater importance in porcellidiid taxonomy than the structure of the genital double-somite, caudal rami and P5 limbs that provided characters upon which specific differences were previously based, Lang (1948), Huys *et al.* (1996).

Because of this, male specimens have been chosen for the holotype for each of the new species named here. The variety of male antennule structure will be shown in the following descriptions of new species and their significance outlined in the General Discussion.

## Methods and terminology

Methods and terminology follow Harris & Robertson (1994) and Harris (2014). The male antennule is examined and measured from the ventral side when fully extended. The following method is used to obtain animals in this condition. Animals are washed from seaweed in a 50/50 mixture of water saturated with CO<sub>2</sub> (from a soda siphon or bottled soda water) and tap water. This appears to anaesthetize or immobilize the animals with antennules extended. Whilst in this state they are fixed with dilute formalin (2–5% formaldehyde) and later preserved in 5% borate buffered formalin (this retains the animal's colouration for a year or more). Two measurements of body length are given:  $L_{\max}$  from rostrum to posterior extremity of the caudal rami, and  $L_{\text{urs}}$  from rostrum to posterior extremity of the genital double-somite.

Drawings, biometric data and description of each species are based on calibrated digital photographs of paratype specimens mounted on slides in 50% glycerol or dissected and mounted in polyvinyl lacto-phenol (PVL). Over a period of many years PVL tends to over-clear specimens, but this can be overcome by using phase optics.

The relative position of the  $\alpha$  and  $\beta$  setae on the caudal ramus is indicated by the Hicks' index defined as the distance of the seta from the posterior extremity of the caudal ramus divided by the length of the ramus expressed as a percentage (i.e.,  $\alpha/\text{ramus length} \times 100$ ).

The naming of setae on the male antennule ( $\delta$ ,  $\pi$ ,  $\sigma$ ,  $\tau$ ) is illustrated in Fig. 29E.

Abbreviations: NHM, Natural History Museum, London; AM, Australian Museum, Sydney; NSM, National Science Museum, Tokyo (now National Museum of Natural Science, Tokyo). All holotype, allotype and paratype specimens of the new species described in this paper have been deposited in

the Australian Museum, Sydney. Paratype specimens of each species have been deposited in the Natural History Museum, London. Type series and samples of most of the species are currently held by the author, but will be deposited in AM, Sydney. Were possible named specimens will be deposited in other Australian Museums.

## Systematics

### Family Porcellidiidae Boeck, 1865

#### Genus *Ravania* gen. nov.

*Porcellidium*.—Thompson & Scott, 1903: 275.—Wells & Rao, 1987: 29; Bodin, 1997: 65; Walker-Smith, 2001: 656; Wells, 2007: 79.

**Type species.** *Ravania wellsi* sp. nov.

**Diagnosis.** Male antennule segment 3 with single denticle at base of anterior process (not comb-like), segment 4 with two tooth-like coupling denticles, no brush-pad or denticulate pad present; anterior of male cephalosome semicircular in outline (not truncated), rostrum oval in ventral view; female cephalosome not truncated; female caudal ramus not rectangular, T1 lateral, posterior border between T1 and T4 rounded or obliquely convex; terminal seta T2 always present, T3 always absent from male and female caudal ramus; female genital double-somite short, narrow (about  $\frac{1}{2}$  width of cephalosome), pointed posteriorly, not clearly divided into anterior and posterior lobes; maxillule endopod with six setae; coxal lobes of maxillipeds touch in midline; female P5 exopods without ventral expansion, extend beyond genital double-somite, but do not touch posteriorly; male P5 trapezoid with one lateral and five terminal setae; spermatophore elongate, ephemeral on female, multiple insemination does not occur.

**Species composition.** *Ravania ravanae* (Thompson & Scott, 1903) comb. nov.; *Ravania wellsi* sp. nov.; *R. doliocauda* sp. nov.

Members of genus known from Indian Ocean (Sri Lanka), sub-tropical coast of Queensland and northern coast of NSW, Australia.

**Etymology.** The specific name *ravanae* has been raised to generic rank as *Ravania* (feminine).

**Remarks.** The arrangement of denticles on the male antennule, rounded anterior to male cephalosome, shape of the female genital double-somite and caudal ramus which lacks T3 are features that distinguish *Ravania* from *Porcellidium* and *Acutiramus*. From the re-description of Wells and Rao (1987) it is clear that *Porcellidium ravanae* belongs to *Ravania* and should be renamed *Ravania ravanae* (Thompson & Scott, 1903) comb. nov.

The description by Wells and Rao (1987) lacks important information about the male antennule and their illustration labelled "female P4" appears to be the male limb, however, it is clear that *R. ravanae* and *R. wellsi* are two distinct species. They differ in the following important details: *R. ravanae* has a small patch of setules on anterior lobe of mandibular palp, border setules on anterior lobe of female genital double-somite, T2 on the caudal ramus is very short and the male P2 endopod has three terminal setae.

### Key to the species of *Ravania*

- 1 Female caudal furca “dolioid” (barrel-shaped), rami not rhomboid. (Plate 1E,F, p. 163) ..... *Ravania doliocauda* sp. nov.
- Female caudal furca pointed, rami rhomboid with T4 at rounded apex ..... 2
- 2 Anterior half of female genital double-somite without border setules. Male P2 endopod with two terminal setae. Short rows of setules at base of each terminal seta on male P5. (Plate 1A,B) ..... *Ravania wellsii* sp. nov.
- Anterior half of female genital double-somite with border setules. Male P2 endopod with three terminal setae. No setules at base of each terminal seta on male P5 ..... *Ravania ravanae* (Thompson & Scott, 1903) comb. nov.

### *Ravania wellsii* sp. nov.

Figs 1–4, Plate 1A

**Type material.** HOLOTYPE adult male, length 0.51 mm, P81198; ALLOTYPE adult female, length 0.58 mm, P81199; PARATYPE specimens, 5 ♀♀, 3 ♂♂, 3 juveniles, P81200, deposited at AM, Sydney. Additional paratypes deposited at NHM, London. All collected from *Eucheuma denticulatum*, sublittoral fringe, Point Vernon, Hervey Bay, Queensland (25°15'S 152°47'E), V. A. Harris, 1998.

**Diagnosis.** Male antennule with short pointed spur or thorn-like denticle at base of  $\delta$  seta on segment 3; anterior half of female genital double-somite without border setules, posterior half with border setules, no seta in lateral indentation between anterior and posterior lobes, half caudal ramus contained in arch of genital double-somite; female caudal ramus rhomboid, terminal seta T2 almost as long as  $\gamma$  seta; male P2 with only two terminal plumose setae on endopod segment 3; female P4 with two spinous setae on endopod; female P5 exopod with one dorsal and two apical setae; male P5 with short rows of ventral setules at base of each terminal seta.

**Biometric data.** *Females* (N = 29): maximum length ( $L_{\max}$ ) mean 0.57 mm, range 0.54–0.61 mm, body length ( $L_{\text{urs}}$ ) mean 0.52 mm, range 0.49–0.56 mm; cephalosome width (W) mean 0.36 mm, range 0.34–0.44 mm; rostrum width 0.08 mm; width of genital double-somite 0.23 mm, length 0.14 mm, arch 0.08 mm; caudal ramus 0.115 mm, width 0.042 mm.

Ratios:  $L_{\text{urs}}/W$  1.44,  $W/R$  4.5; genital double-somite w/l 1.65, arch 57% of length; caudal ramus 22% of  $L_{\text{urs}}$ , ramus l/w 2.7, Hicks' index for  $\beta$  68%.

*Males* (N = 23): length ( $L_{\max}$ ) mean 0.51 mm, range 0.49–0.54 mm, body length ( $L_{\text{urs}}$ ) mean 0.48 mm, range 0.46–0.51 mm; cephalosome width 0.35 mm. antennule (N = 3, fully extended 0.125 mm; spermatophore 0.18 × 0.065 mm.

Ratios:  $L_{\text{urs}}/W$  1.4; antennule 24.5% of  $L_{\text{urs}}$ , antennule segment 2 31%, segment 3+4 35%, dactylus 21% of antennule length; spermatophore 37% of body length  $L_{\text{urs}}$ .

**Description.** *Adult females* (Fig. 1A; Plate 1A, p. 163): colouration, pale red with central cephalosome and metasome segments 1 and 2 deep red, metasome segments 3 and 4 pale red, genital double-somite and caudal rami deep red. Some animals are pale red or colourless. Eye spot

dark brown. Anterior of cephalosome broadly rounded, rostrum prominent, narrow with hyaline anterior border. Dorsal surface ornamented with pits (4  $\mu\text{m}$ ). Hyaline border 8  $\mu\text{m}$  wide, without striations. Sensillum on epipleural lobe of second metasome segment conspicuous, longer than other species. Labrum without central patch of setules or ridge plates. Genital double-somite (Fig. 1E) with slight indentation that marks the boundary between anterior and posterior lobes, anterior lobe short, convex, with thickened edge but no setules, posterior lobe triangular, pointed posteriorly with border setules. Arch of genital double-somite deep, encloses about half length of caudal ramus, dorsal surface with pits. Genital opening as in Fig. 1F. Caudal rami (Fig. 1D) rhomboid, length about 2½ times width, sides almost parallel, oblique posterior edge slightly convex, apex broadly rounded with pinnate T4. Dorsal surface with prominent network of ridges,  $\beta$  seta ⅓ way down ramus,  $\gamma$  seta about ½ way along oblique edge. Medial edge with border setules up to the level of  $\beta$  seta, lateral edge slightly convex with border setules distally, T1 unipinnate at lateral corner of oblique edge, T2 plain about as long as  $\gamma$  seta, T3 absent, posterior border with fine setules from T1 to T4. Structure and setation of mouthparts and ambulatory limbs typical of family. Antenna (Fig. 2A) exopod with five plumulose setae and one finely serrulate spinous seta, endopod segment 2 with two lateral setae, geniculate setae with plain end segment, claw fine comb-like. Mandible (Fig. 2D, E, F) without setules on anterior lobe of palp. Maxillule (Fig. 2B), endopod with six setae, exopod with one bulbous seta. Maxilla (Fig. 2H) and maxilliped (Fig. 2G) typical. No area of denticulate setules on P1 endopod (Fig. 2C). Serrulate spinous seta on segment 3 of P2 endopod about ½ length of endopod (Fig. 3C). Serrulate spinous seta on segment 2 of P3 endopod (Fig. 3A) shorter than endopod (0.8:1), large serrate spinous seta on segment 3 longer than endopod (1.3:1). Internal seta on segment 2 and segment 3 of P4 endopod strong spinous, other setae plumose (Fig. 3F). Dorsal surface of P5 exopod with pits, internal seta on baseoendopod serrulate, about ½ length of exopod, exopod lanceolate with one dorsal seta and two apical setae (Fig. 3E). P5s reach beyond genital double-somite to extremity of caudal rami, but do not touch posteriorly. Females carry six large eggs.

*Adult males* (Fig. 1B; Plate 1B, p. 163). Colouration similar to female, but posterior region of most specimens is pale red or colourless. Anterior of cephalosome rounded (not truncated), rostrum projects anteriorly, in ventral view rostrum appears



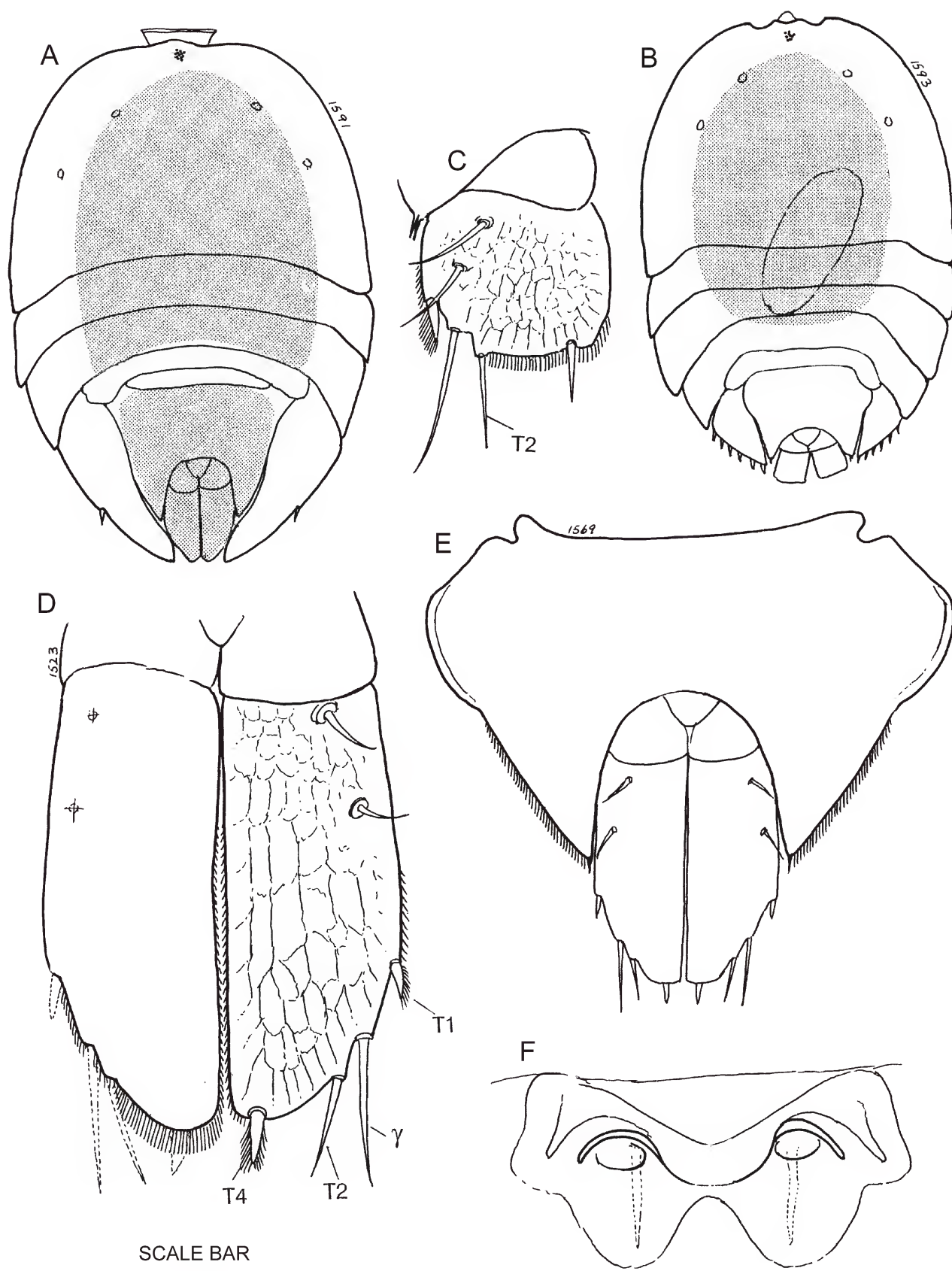


Figure 1. *Ravania wellsi* sp. nov. Female: (A) adult; (D) caudal ramus (left ventral, right dorsal); (E) genital double-somite and caudal rami; (F) genital opening. Male: (B) adult; (C) caudal ramus. Scale bar: A, B = 0.37 mm. C, D = 0.08 mm. E = 0.15 mm. F = 0.06 mm.



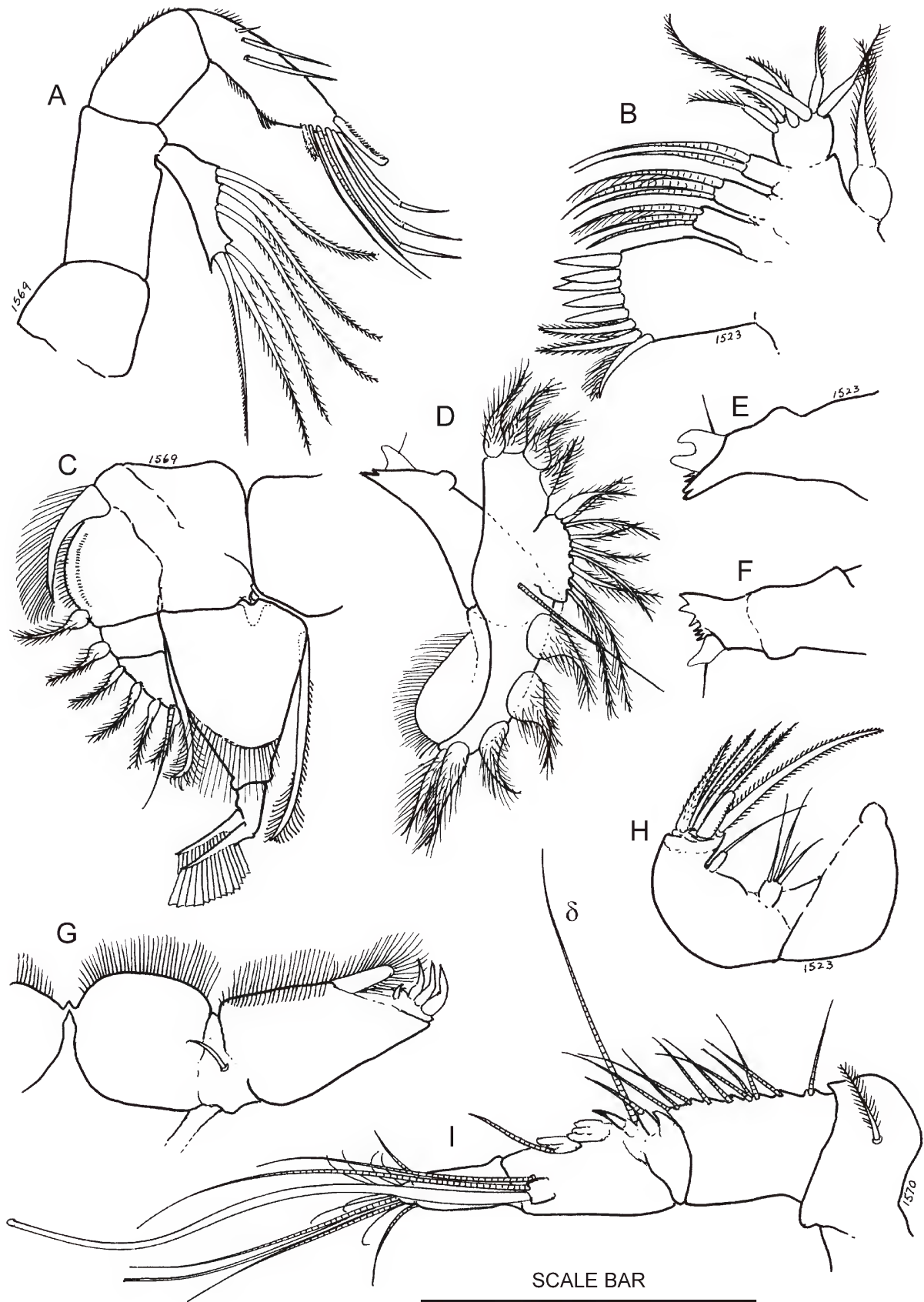


Figure 2. *Ravania wellsi* sp. nov. Female: (A) antenna; (B) maxillule; (C) P1; (D) mandible; (E, F) left and right molar process; (G) maxilliped; (H) maxilla. Male: (I) antennule (ventral). Scale bar: A, I = 0.08 mm. B = 0.06 mm. C, D = 0.14 mm. E, F, H = 0.1 mm. G = 0.12 mm.

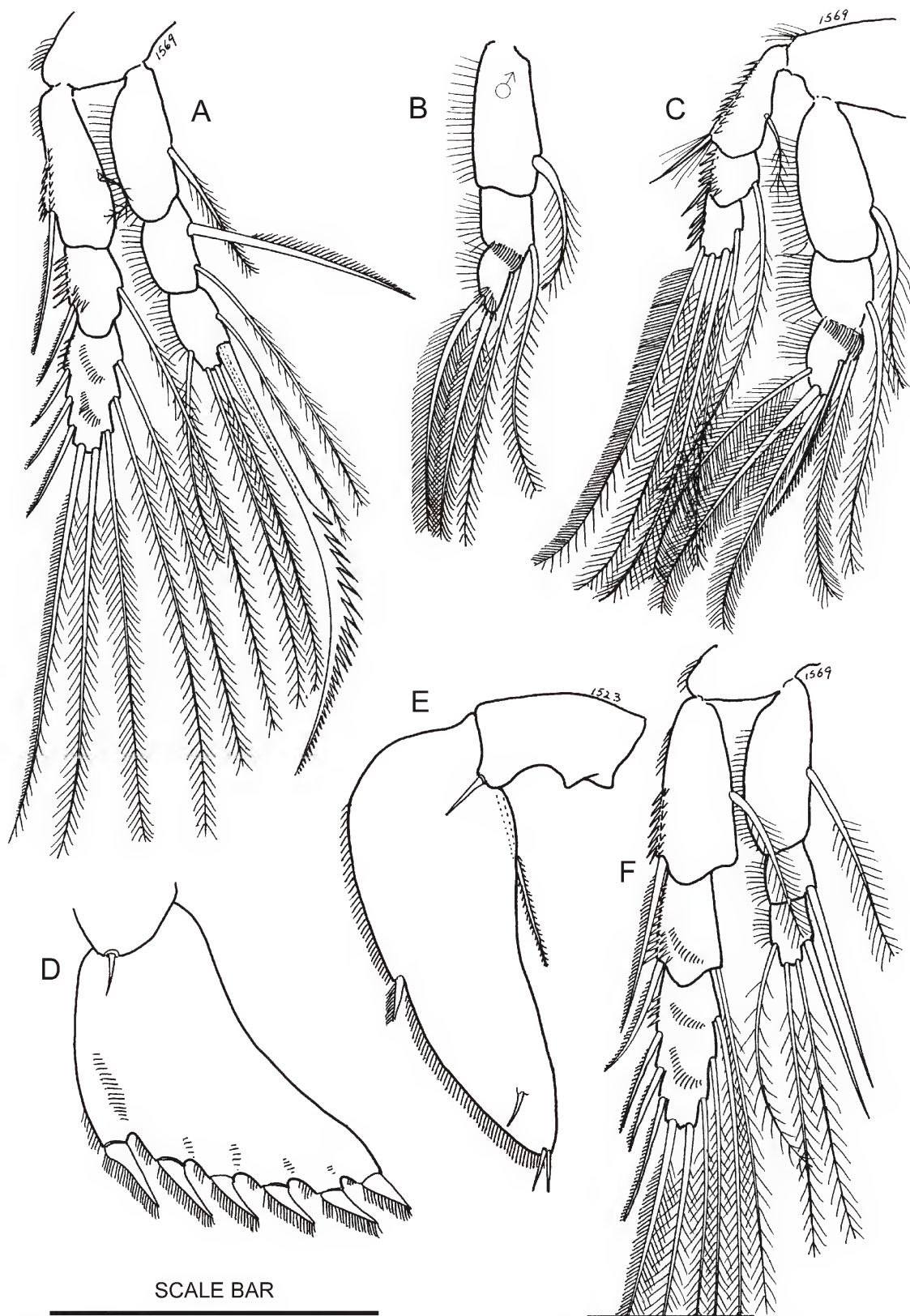


Figure 3. *Ravanaia wellsi* sp. nov. Female: A, P3. C, P2. E, P5 (dorsal). F, P4. Male: B, P2 endopod. D, P5 (ventral). Scale bar: A, D, E = 0.1 mm. B, C = 0.14 mm. F = 0.08 mm.

oval with keeled anterior half (Figs 4B, C). Dorsal pits and hyaline border as for female. Caudal rami quadrate, slightly longer than wide (Fig. 1C). Dorsal surface with network of ridges, medial edge straight with border setules distally, lateral

edge convex with border setules distally. Terminal seta T1 unipinnate, recessed, T2 plain, almost as long as  $\gamma$  seta, T3 absent, T4 plain, set in from medial corner. Posterior border straight, fringed with fine setules. Antennule (Figs 2I, 4D)

characteristic of genus. Seta on segment 1 plumose, segment 3 with short, pointed spine-like denticle close to anterior lobe,  $\delta$  seta very long ( $\frac{1}{2}$  length of antennule), projects anteriorly (Fig. 2I), two tooth-like coupling denticles on segment 4, aesthetasc extremely long (almost as long as fully extended antennule (Fig. 2I), dactylus long, cylindrical. Endopod of P2 with two plumose terminal setae (Fig. 3B). No spinous setae on P4 endopod, all setae plumose. Dorsal surface of P5 exopod with pits, ventral setules at base of each terminal seta (Fig. 3D).

**Etymology.** The species has been named in recognition of Dr J. B. J. Wells' contribution to the taxonomy of the Harpacticoida.

**Distribution.** Type series collected from *Eucheuma denticulatum*, Point Vernon, Hervey Bay, PV4. 7/98, 41 ♀♀ (21 with eggs), 26 ♂♂, 14 juveniles. Also found on *Zonaria* sp., PV8, 8/00, 12 ♀♀, 14 ♂♂ at the same location. The species has been recorded at Arrawarra headland, northern NSW, on *Caulerpa vesiculosus* and *Dilophus* sp. V. A. Harris, 1982, 2000.

### *Ravania doliocauda* sp. nov.

Figs 4–8, Plate 1E

**Type material.** HOLOTYPE adult male, length 0.66 mm, P81195; ALLOTYPE adult female, length 0.75 mm, P81196; PARATYPE specimens, 10 ♀♀, 6 ♂♂, P81197, deposited at AM, Sydney. Additional paratypes deposited at NHM, London. All collected from *Zostera capricornia* at Pulgul Creek mud flats, Urangan, Hervey Bay, Queensland (25°17'S 152°52'E), V. A. Harris, 30 Nov. 2002.

**Diagnosis.** Large denticle with serrated crown at base of  $\delta$  seta on segment 3 of male antennule; female genital double-somite narrow ( $< \frac{1}{2}$  cephalosome width), no indication of division into anterior and posterior lobes, narrows to a point posteriorly, border setules absent except for a few at posterior apex, caudal rami excluded from posterior arch of genital double-somite; caudal furca dolioid (barrel-shaped in outline), rami long ( $l/w > 2$ ), taper posteriorly, lateral and posterior edge convex, T1 lateral ( $\frac{1}{2}$  way down ramus),  $\gamma$  seta recessed at posterolateral corner; medial patch of setules on labrum; male P2 endopod with three terminal setae.

**Biometric data.** *Females* (N = 32): maximum length ( $L_{\max}$ ) mean 0.75 mm, range 0.72–0.78 mm, body length ( $L_{\text{urs}}$ ) mean 0.65 mm, range 0.62–0.69 mm; cephalosome width (W) mean 0.45 mm; rostrum width (R) 0.10 mm; genital double-somite length 0.135 mm, width 0.23 mm, arch 0.03 mm; caudal ramus length 0.13 mm, maximum width 0.06 mm ( $\frac{1}{2}$  down ramus).

Ratios:  $L_{\text{urs}}/W$  1.44;  $W/R$  4.5–4.75; genital double-somite width 50% of body width, arch 22% of length; caudal ramus 20% of  $L_{\text{urs}}$ , ramus  $l/w$  2.16, terminal seta T1 located 54% down lateral edge of ramus, Hicks' index for  $\alpha$  85%, for  $\beta$  70%.

*Males* (N = 20): maximum length ( $L_{\max}$ ) mean 0.66 mm, range 0.62–0.67 mm; cephalosome width (W) mean 0.44 mm; rostrum length 0.055 mm (ventral); caudal ramus length 0.05 mm, width 0.05 mm; antennule length fully extended 0.165 mm; spermatophore  $0.22 \times 0.09$  mm.

Ratios:  $L_{\max}/W$  1.5; caudal ramus 7.5% of  $L_{\max}$ , ramus  $l/w$  1.0; antennule 20% of  $L_{\max}$ , antennule segment 2 24%,

segment 3+4 36%, dactylus 24% of antennule length; spermatophore 33% of body length  $L_{\max}$ .

**Description.** *Adult females* (Fig. 5A; Plate 1E, p. 163): colourless or very pale yellow (but see remarks below), outline of body oval, cephalosome semicircular with prominent rostrum, dorsal pits inconspicuous, very few dorsal sensilla mostly towards edge of cephalosome. Hyaline border clear, 7  $\mu\text{m}$  wide (Fig. 5F). Labrum with central patch of very short setules (Fig. 6J). Genital double-somite (Fig. 5B, C) narrow, no epipleural expansion or division into anterior and posterior lobes, posterior half narrow (equals width of caudal rami), very fine filiform setules towards acutely pointed posterior, dorsal surface with transverse rows of shallow pits, no cleft, notch or scar to indicate boundary between anterior and posterior regions. Caudal arch shallow, encloses most of the anal segment, but caudal rami are excluded from arch. Female genital opening (Fig. 5D, E). Caudal furca dolioid (barrel-shaped in outline) (Fig. 5B). Each ramus narrows posteriorly, maximum width at level of  $\beta$  seta, lateral edge convex with border setules, medial edge without setules, posterior edge slightly convex, dorsal surface with pits and reticulate marking posteriorly (Fig. 6I). Terminal seta T1 halfway down lateral edge,  $\gamma$  seta recessed, T4 set in from medial corner. T3 absent. Antennule with pinnate seta on segment 1. Structure and setation of mouthparts and ambulatory limbs typical of family. Basis of antenna with row of small triangular setules (Fig. 6D), segment 2 of endopod with two lateral setae, geniculate setae with plain end segment, claw with fine comb-like edge. Mandible (Fig. 6H), maxillule (Fig. 6A), maxilla (Fig. 6C) and maxilliped (Fig. 6B). Segment 1 of P1 exopod (Fig. 6G) with crescent of fine setules parallel to edge, no area of denticulate setules on endopod. Spinous seta on P2 endopod segment 3 more than  $\frac{1}{2}$  endopod length (0.6:1) (Fig. 7C). Serrate spinous seta on segment 2 of P3 endopod almost as long as endopod (Fig. 7B), large serrate spinous seta on segment 3 longer than endopod (1.4:1). P4 endopod with internal spinous seta on segment 2 and first (internal) spinous seta on segment 3 plain (Fig. 7E). Baseoendopod of P5 with long ventral seta ( $\frac{1}{2}$  length of exopod), exopod broad ( $l/w = 1.67$ ), ovate with acute apex (Fig. 6E), strong ventral falciform ridge, long border setules, one subterminal dorsal seta and two apical setae (Fig. 6F), P5s extend back  $\frac{3}{4}$  length of caudal rami and compensate for the narrow genital double-somite by forming most of the roof to the brood chamber. Females carry 10 eggs per brood.

*Adult males* (Fig. 8A; Plate 1F, p. 163). Colourless or very pale yellow. Outline of body oval, anterior of cephalosome semicircular (not truncated), rostrum keeled, oval in ventral view (Fig. 8C). Dorsal pits, sensilla and hyaline border as for female. Caudal ramus (Fig. 8E) quadrate, setation similar to female T1 lateral, T3 absent, T4 at medial corner. Antennule (Fig. 7F) with pinnate seta on segment 1,  $\delta$  seta on segment 3 long (equal to segment 3+4+ dactylus in length), points forward, coupling denticle on segment 3 large with serrated crown, two tooth-like denticles on segment 4 (Fig. 8F), dactylus  $\frac{2}{3}$  length of segment 3+4, apex pointed (Fig. 8G). Other limbs as for female except P2 (Fig. 7D) has three terminal setae on endopod (two plumose, one serrulate spinous). P5 acutely trapezoidal, first (lateral) seta of different shape to terminal setae (Fig. 8D), first row of ventral setules about 16, row of four or five setules at base



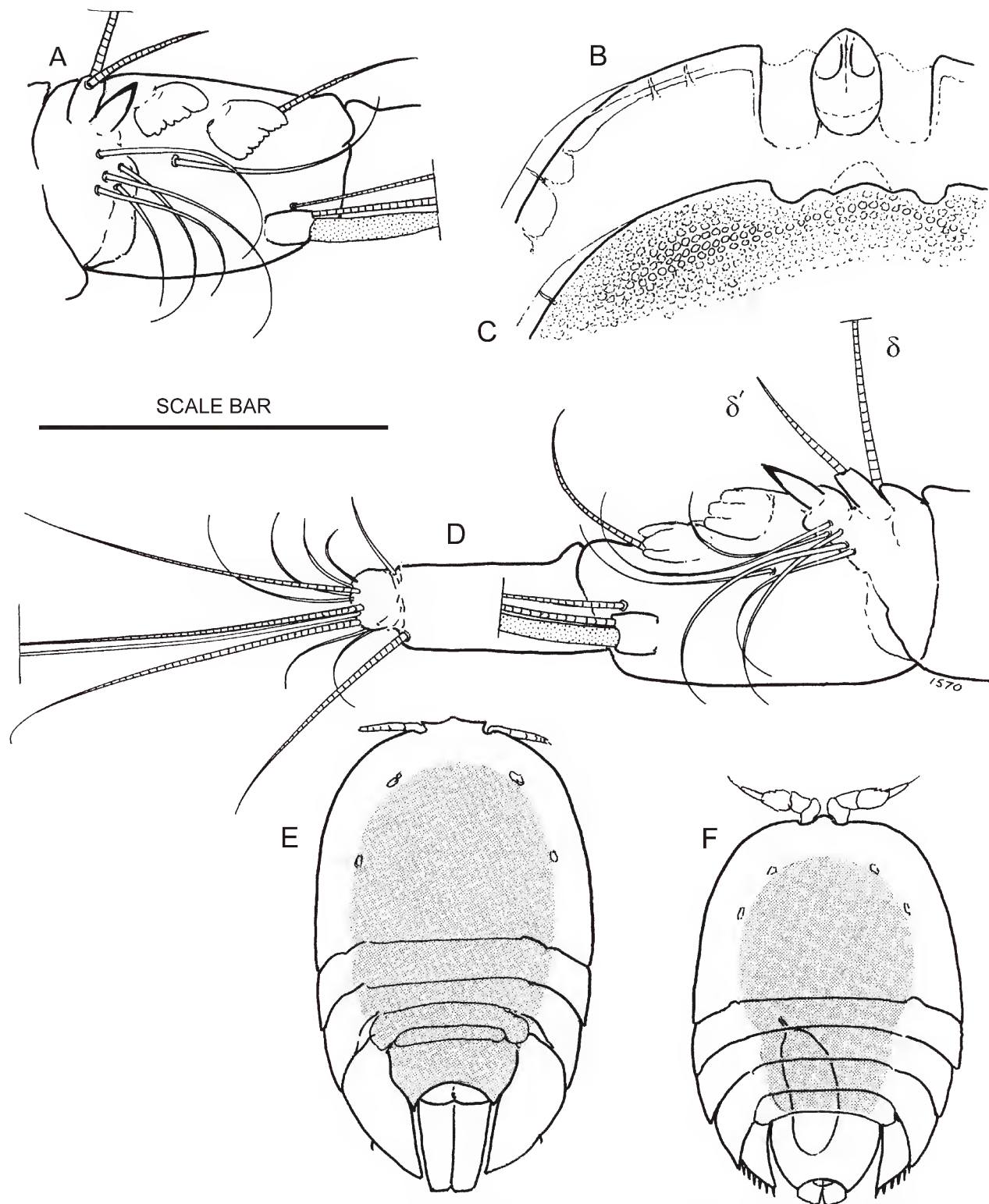


Figure 4. *Ravania wellsi* sp. nov. Male: (A) antennule coupling denticles; (B, C) anterior cephalosome (ventral, dorsal); (D) antennule (detail of dactylus). *Ravania doliocauda* sp. nov. coloured variety from Cairns, northern Queensland: (E) adult female; (F) adult male. Scale bar: A, D = 0.04 mm. B, C = 0.15 mm. E, F = 0.58 mm.

of each terminal seta. Spermatophore relatively large ( $\frac{1}{3}$  body length).

**Etymology.** The specific name refers to the outline of the caudal furca (L. *doliolum* = a small barrel or cask + *cauda* = tail).

**Remarks.** All specimens collected at low tide from seagrass on the Pulgul Creek mudflats at the Urangan collection site are heavily contaminated with silt particles plus a wide variety of attached organisms (bacteria, protozoa, moulds, unicellular algae, diatoms, filamentous algae etc.). This makes critical observation of fine structure difficult or

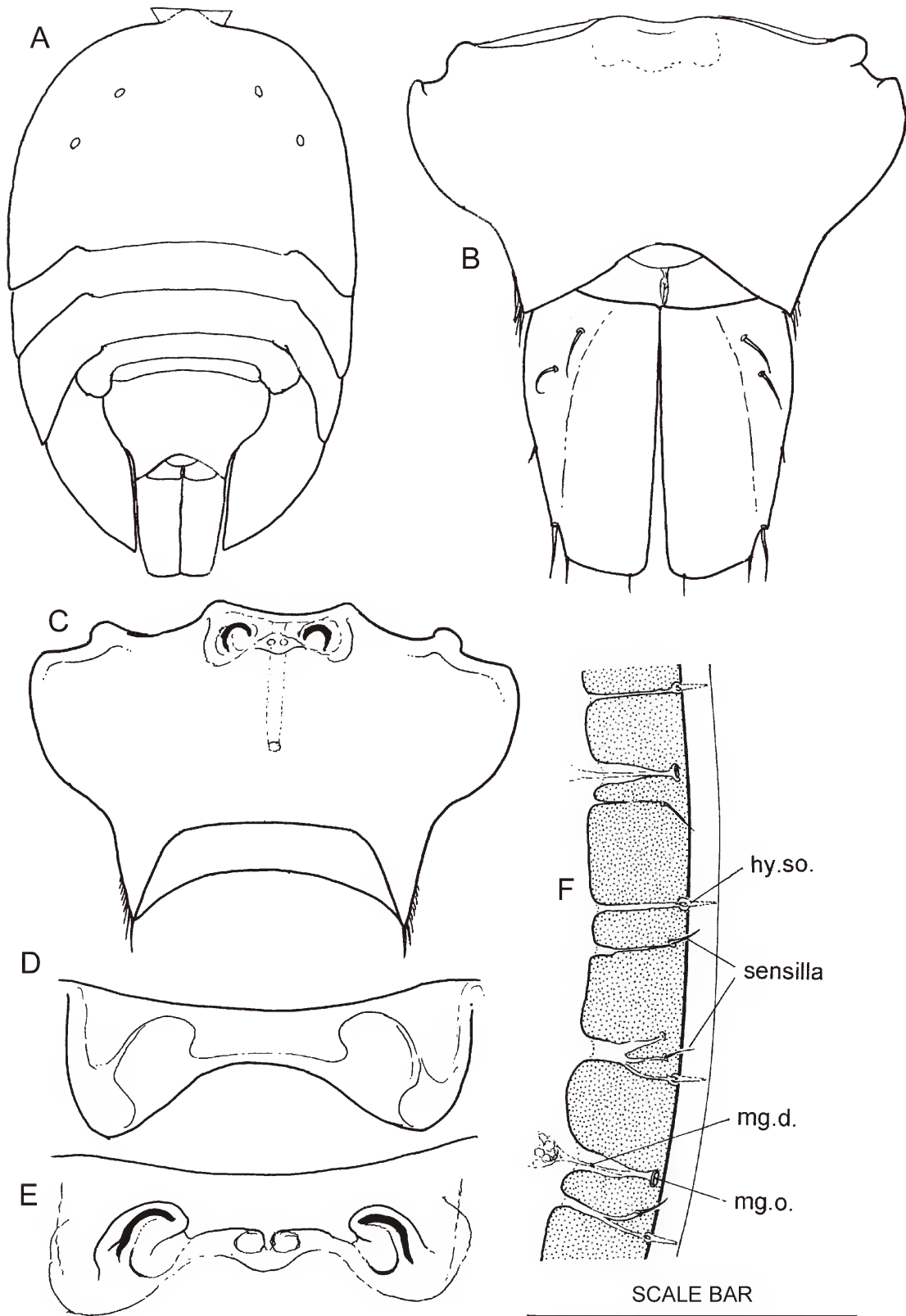


Figure 5. *Ravania doliocauda* sp. nov. Female: (A) adult; (B) genital double-somite and caudal rami; (C) genital double-somite (ventral); (D, E) Genital opening (superficial and deep focus); (F) cephalosome border (*hy.so.* hyaline border sense organ; *mg.d.* marginal gland duct; *mg.o.* opening to marginal gland). Scale bar: A = 0.45 mm. B, C = 0.15 mm. D, E = 0.06 mm. F = 0.08 mm.

impossible. Various methods using detergents, enzymes and ultrasonic vibration have been used with varying success to clean the animals before dissection, but such treatment often

destroys the fine structure of setae and setules.

Apart from their tolerance to a muddy environment, this species can survive wide environmental temperature and

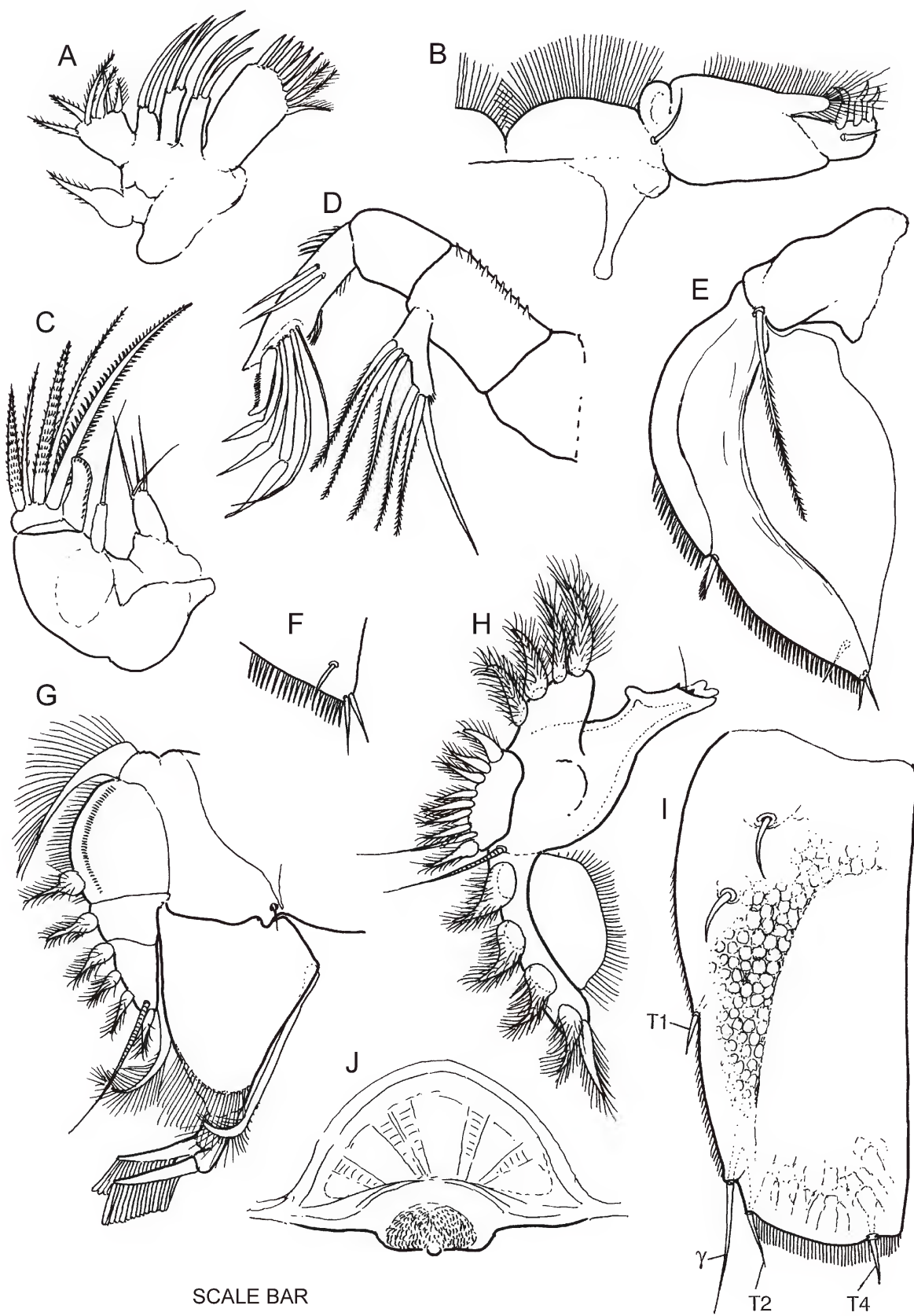


Figure 6. *Ravania doliocauda* sp. nov. Female: (A) maxillule; (B) maxilliped; (C) maxilla; (D) antenna; (E) P5 (ventral); (F) apex of P5; (G) P1; (H) mandible; (I) caudal ramus (dorsal); (J) labrum. Scale bar: A, C = 0.08 mm. B, D, H, I, J = 0.1 mm. E = 0.19 mm. G = 0.14 mm.



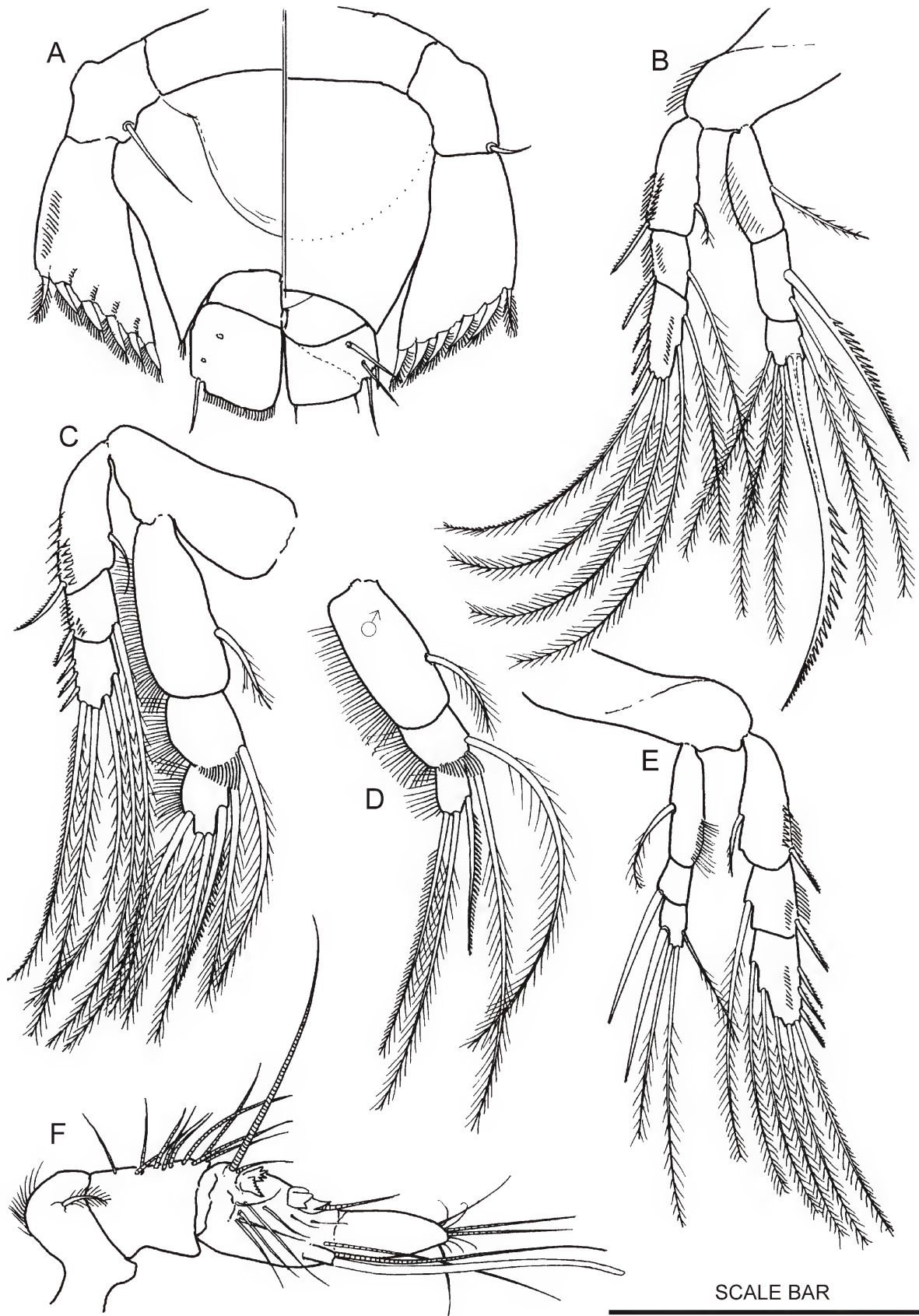


Figure 7. *Ravania doliocauda* sp. nov. Male: (A) genital somite, P5 and caudal rami (ventral, dorsal); (D) P2 endopod; (F) antennule. Female: (B) P3; (C) P2; (E) P4. Scale bar: A, C, D, E = 0.14 mm. B = 0.19 mm. F = 0.1 mm.

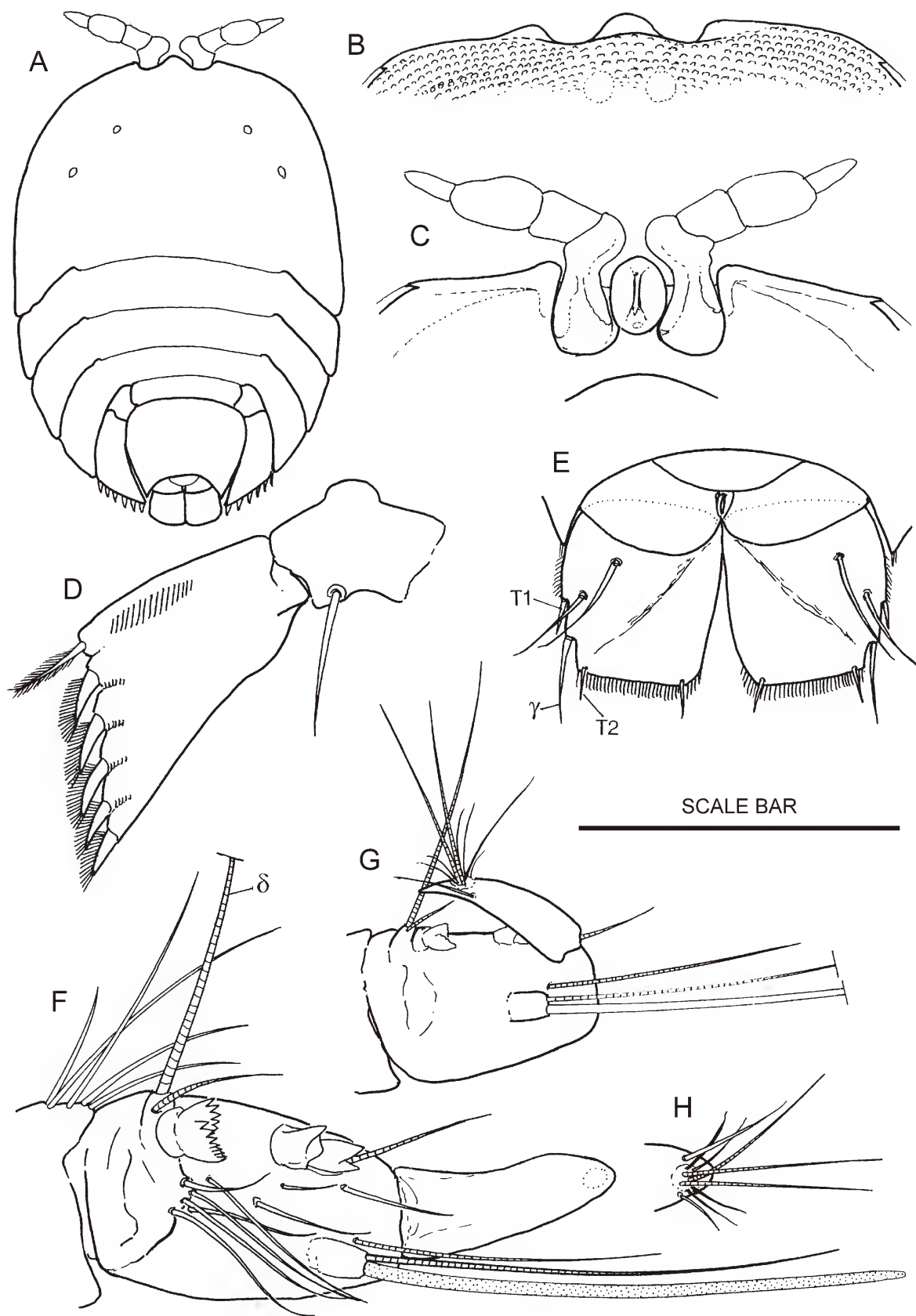


Figure 8. *Ravania doliocauda* sp. nov. Male: (A) adult; (B, C) anterior of cephalosome (dorsal, ventral showing rostrum); (D) P5 (ventral); (E) caudal rami; (F) antennule showing coupling denticles; (G, H) dactylus of antennule. Scale bar: A = 0.45 mm. B, C = 0.23 mm. D = 0.11 mm. E = 0.1 mm. F = 0.06 mm. G = 0.08 mm.

salinity changes. Low water during spring tides tend to occur about midday or early afternoon at Urangan leaving the seagrass beds exposed to solar radiation for up to three hours. On 30 November 2002 at 12.30 pm when the type population sample was collected, water temperature in very shallow pools containing seagrass was recorded at 31°C, despite the fact that the weather was overcast with showers. Heavy rain occurring during the low tide period, particularly during the cyclone season, will flood the mud flats and subjects all organisms living there to lowered salinity or fresh water.

**Distribution.** The type series (PCK 3. 11/02) was collected from *Zostera capricornia* on mud flats at low water spring tide. It comprised 147 ♀♀ (91 carrying eggs), 122 ♂♂ and 26 copepodids. This species has been collected from another seagrass *Cymodocea serrulata* in the same area, (PCK 1. 4/97. 116 ♀♀ (67 with eggs), 108 ♂♂ and 21 copepodids), but it has not been found on two other seagrasses, *Halophila ovalis* and *H. spumifera*, both abundant in the same area, V. A. Harris 1997, 2002. A coloured form of *R. doliocauda* with large red area on back (Fig. 4E, F) was collected from sea grass (? *Zostera capricornia*) growing on coral sand in shallow water inside the coral reef at Green Island, Cairns, Queensland (16°43'S 146°E) 4 ♀♀, 2 ♂♂, V. A. Harris 1973.

## Genus *Synurus* gen. nov.

*Porcellidium*.—Ummerkuty, 1970: 158.

**Type species.** *Synurus ctenocheirus* sp. nov.

**Diagnosis.** Male genital double-somite fused to metasome segment 4 and baseopod of P5; epipleural lobe of male metasome segment 3 long, stretches back to posterior extremity of caudal ramus; male P5 exopod ovate (not trapezoidal) with one lateral seta, terminal setae atrophied or absent; seta T1 absent from male and female caudal ramus; segment 3 of P2, P3 and P4 exopod with only two external setae; anterior of male cephalosome deeply concave; anterior of female cephalosome truncated; female P5 exopod without ventral expansion, P5s reach beyond genital double-somite but do not touch posteriorly; spermatophore elongate, ephemeral on female.

**Species composition.** *Synurus unicus* (Ummerkuty, 1970) comb. nov.; *S. ctenocheirus* sp. nov.

The genus is known from Gulf of Mannar, Sri Lanka (Ceylon), Okinawa, Japan and the Great Barrier Reef, Australia.

**Etymology.** The name *Synurus* (masculine) refers to the fusion of the anal segment with the caudal rami on female specimens of the type species (G. *syn* = together, conjoint + *oura* = tail).

**Remarks.** Males of this genus are unique among the Porcellidiidae in having an ovate P5 exopod with long lateral seta and terminal setae that are atrophied or absent. This limb strongly resembles the general form of the female P5, except for the absence of a ventral falciform ridge and dorsal setae.

## *Synurus ctenocheirus* sp. nov.

Figs 9–12, Plate 1G, H

**Type material.** HOLOTYPE adult male, length 0.55 mm, P81213; ALLOTYPE adult female, length 0.68 mm, P81214; PARATYPE specimens, 6 ♀♀, 4 ♂♂, P81215, deposited at AM, Sydney. Additional paratypes deposited at NHM, London. All washed from seagrass *Zostera* sp., collected at Green Island, Cairns, Queensland, Australia (16°41'S 145°56'E), V. A. Harris, 1973.

**Diagnosis.** First (proximal) claw on P1 endopod ctenoid (comb-like) with recurrent teeth, second claw lamelliform; female caudal ramus fused to anal segment; male antenna with seta on basis (absent from females, Fig. 10A); male P5 exopod with long lateral seta, terminal setae absent except for two small spine-like atrophied setae; female rostrum extremely broad ( $\frac{1}{3}$  cephalosome width).

**Biometric data.** *Females* (N = 10): maximum length ( $L_{\max}$ ) mean 0.68 mm, range 0.67–0.70 mm, body length ( $L_{\text{urs}}$ ) mean 0.66 mm, range 0.65–0.68 mm; cephalosome width 0.44 mm, range 0.43–0.45 mm; rostrum 0.14 mm; genital double-somite width 0.18 mm, length 0.2 mm, arch 0.08 mm; caudal ramus length 0.078 mm, width 0.022 mm [length of caudal ramus from point of fusion with the anal segment (indicated by a slight notch, see Fig. 9)].

Ratios:  $L_{\text{urs}}/W$  1.5;  $W/R$  3.0, cephalosome length 60% of  $L_{\max}$ ; genital double-somite w/l 0.9, height of arch 40% of length; caudal ramus l/w 3.8, 12% of  $L_{\text{urs}}$ , Hicks' index for  $\beta$  60%, distance between  $\alpha$  and  $\beta$  setae 25% of ramus length.

*Males* (N = 10): maximum length (measured from anterior edge of shoulder  $L_{\max}$ ) mean 0.55 mm, body length (from rostrum  $L_{\text{urs}}$ ) mean 0.48 mm, range 0.47–0.50 mm; cephalosome width 0.37 mm; caudal ramus length 0.047 mm, width 0.028; antennule length (fully extended) 0.10 mm; spermatophore  $0.09 \times 0.02$  mm.

Ratios:  $L_{\text{urs}}/W$  1.3,  $L_{\max}/W$  1.5; cephalosome length 67% of  $L_{\max}$ ; caudal ramus l/w 1.7; antennule 18% of body length ( $L_{\text{urs}}$ ), antennule segments 3+4 57% and dactylus 18% of antennule length; spermatophore 18% of body length ( $L_{\text{urs}}$ ).

**Description.** *Adult females* (Fig. 9A; Plate 1G, p. 163): colour lemon yellow. Body outline an ellipse ( $e = 0.814$ ) strongly truncated anteriorly with slight bulge in midline. Cephalosome length greater than half maximum length of animal. Rostrum very wide ( $\frac{1}{3}$  body width). Dorsal pits inconspicuous (1–1.5  $\mu\text{m}$ ), a few dorsal sensilla present. Hyaline border clear, 7  $\mu\text{m}$  wide (Fig. 9D), surrounds cephalosome, ducts of marginal glands open dorsally. Genital double-somite cordate (Fig. 9B), length greater than width, no notch or scar to indicate boundary between anterior and posterior lobes, no anterolateral ridges (rugosities), border setules very small, posterior extremity pointed, terminated by four or five small setules. Posterior arch deep, nearly all of rami enclosed in arch. Caudal ramus long, narrow, rhomboid with parallel sides (Fig. 9F), fused to anal segment. Dorsal surface with very small dorsal pits ( $< 1 \mu\text{m}$ ) and parabolic ridge on each ramus that fits the edge of genital double-somite arch. Seta T1 absent,  $\gamma$  seta at lateral corner, posterior border oblique, T4 at rounded apex, T2 and T3 very close mid-way along oblique edge (they tend to lie parallel to edge), terminal fringe of very fine setules between T3 and T4 (Fig.



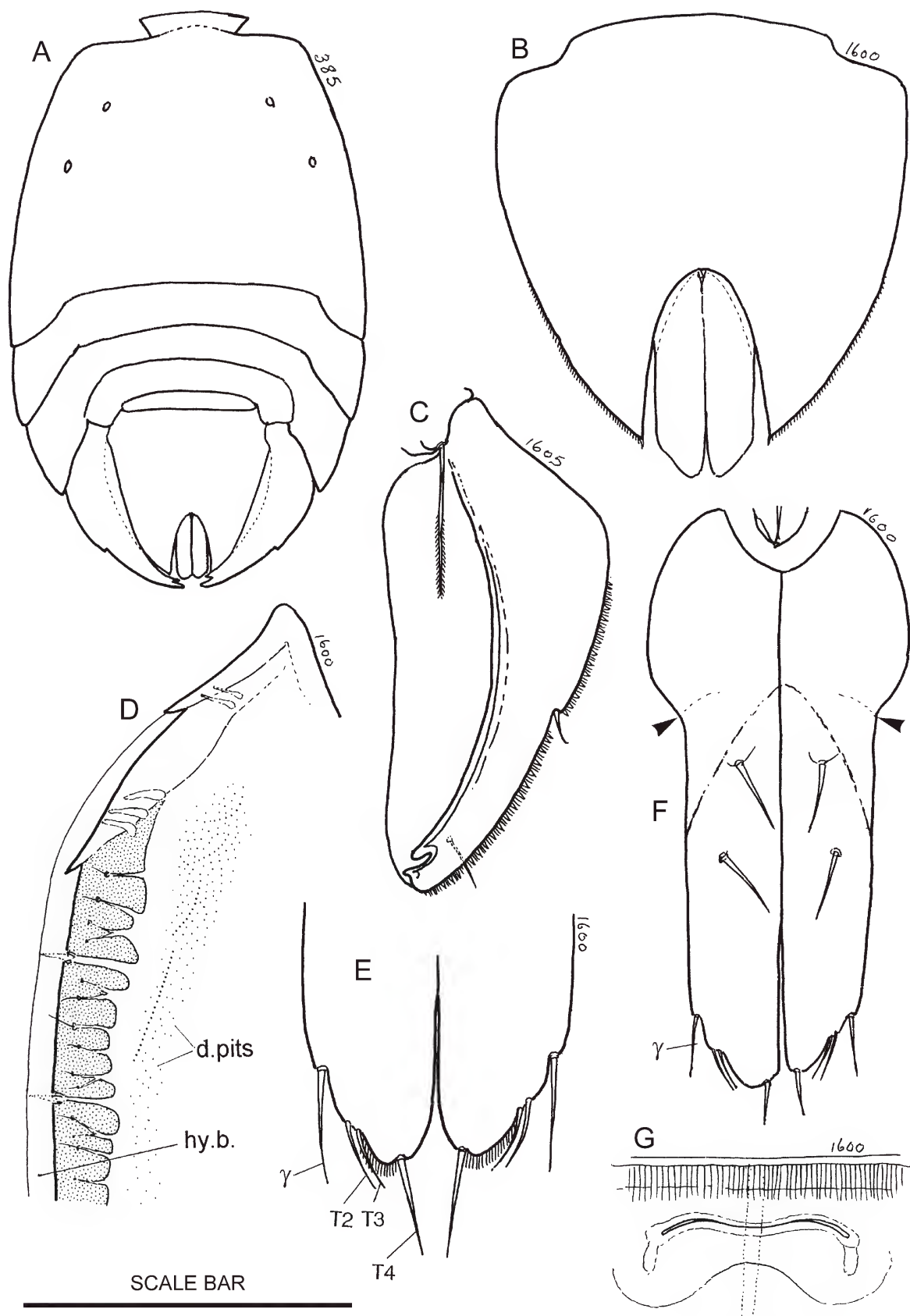


Figure 9. *Synurus ctenocheirus* sp. nov. Female: (A) adult; (B) genital double-somite; (C) P5 (ventral); (D) edge of cephalosoma (*d. pits*, dorsal pits; *hy.b.* hyaline border); (E) detail of terminal setae on caudal rami; (F) caudal rami showing fusion of anal segments with rami (arrow marks point of fusion); (G) genital opening. Scale bar: A = 0.45 mm. B, C = 0.15 mm. D, F = 0.08 mm. E = 0.06 mm. G = 0.12 mm.

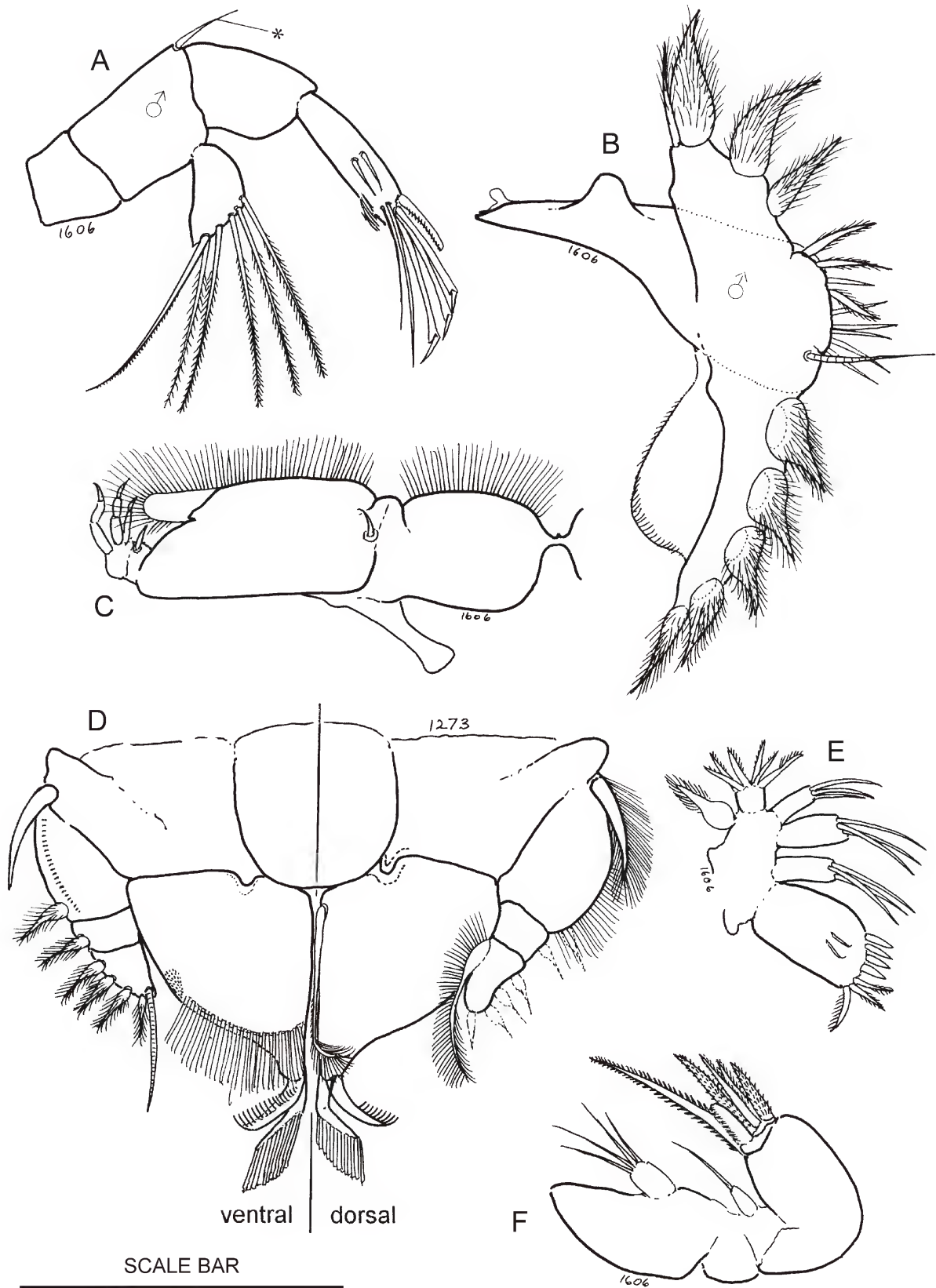


Figure 10. *Synurus ctenocheirus* sp. nov. Male: (A) antenna (\* seta on basis); (B) mandible. Female: (C) maxilliped; (D) P1; (E) maxillule; (F) maxilla. Scale bar: A = 0.1 mm. B, C, E, F = 0.08 mm. D = 0.14 mm.

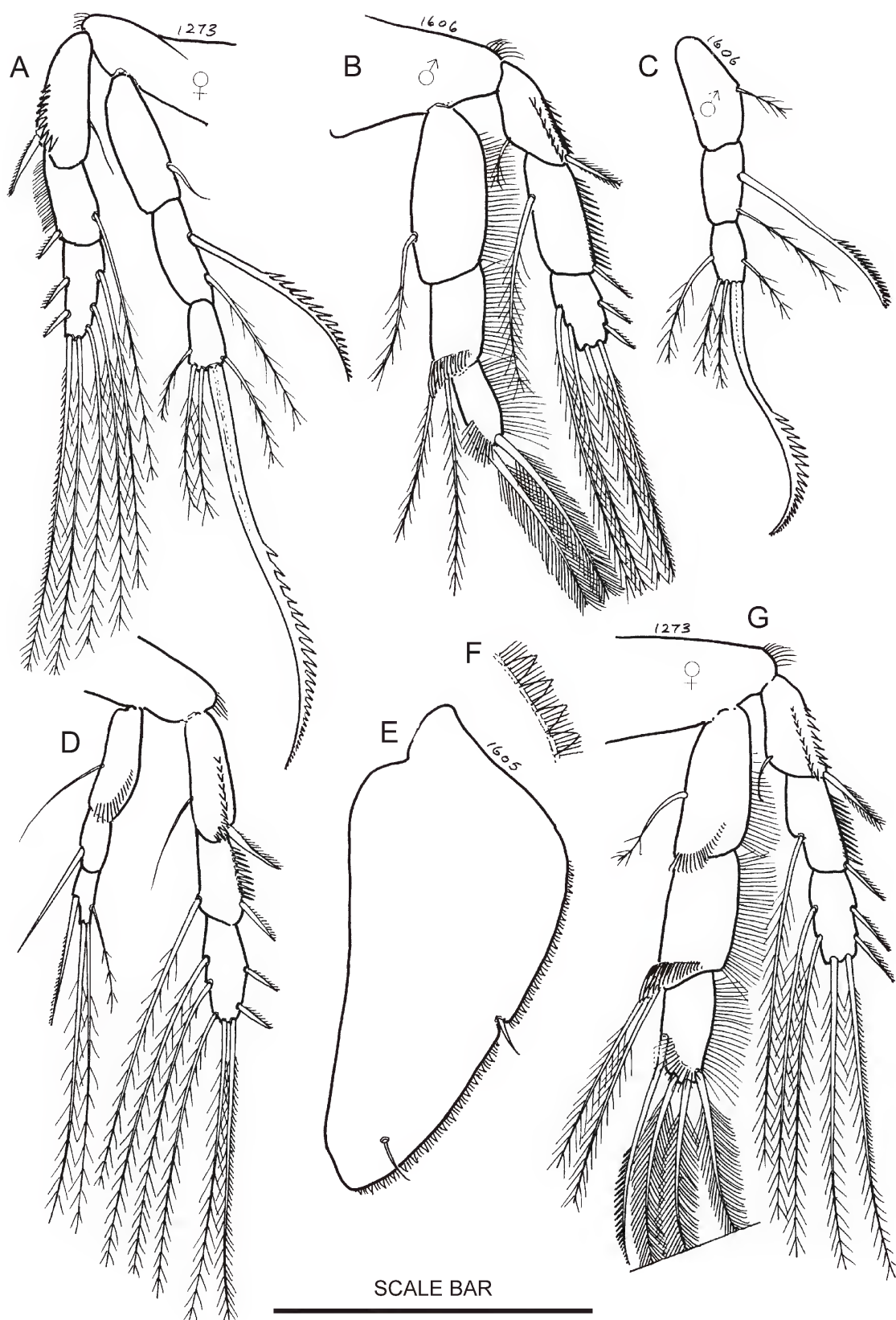


Figure 11. *Synurus ctenocheirus* sp. nov. Female: (A) P3; (D) P4; (E) P5 (dorsal); (F) border setules of P5; (G) P2. Male: (B) P2; (C) P3 endopod. Scale bar: A, C, D, G = 0.14 mm. B = 0.1 mm. E = 0.17 mm.



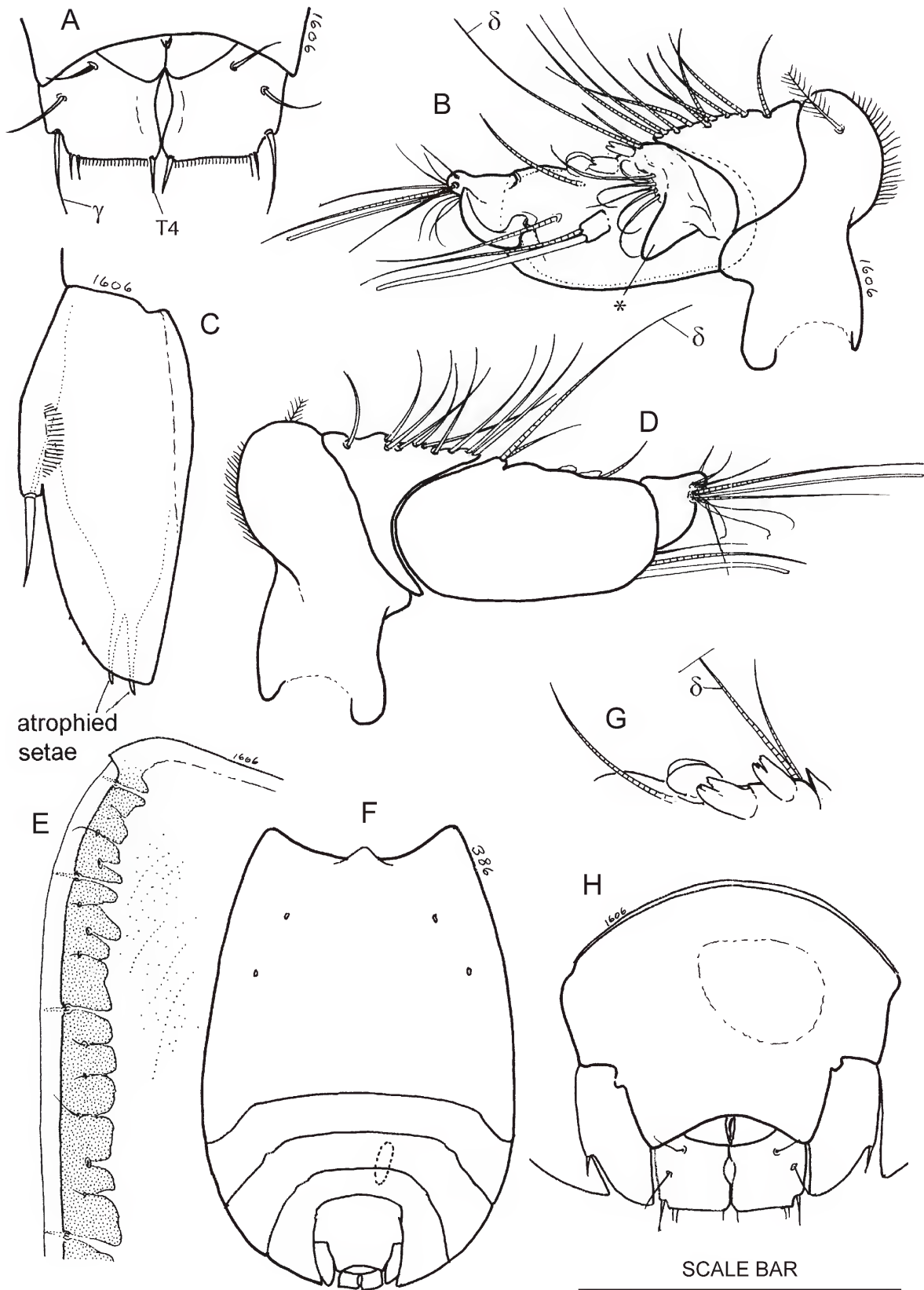


Figure 12. *Synurus ctenocheirus* sp. nov. Male: (A) caudal rami; (B) antennule, ventral (\* ventral process); (C) P5 (ventral); (D) antennule, dorsal; (E) edge of cephalosome; (F) adult with spermatophore; (G) coupling denticles on antennule; (H) genital double-somite and caudal rami (showing fusion of genital double-somite with metasome segment 4 and P5 baseoendopod. Scale bar: A, B, D, E, H = 0.08 mm. C = 0.06 mm. F = 0.45 mm. G not to scale.

9E). Structure and setation of mouthparts and ambulatory limbs typical of family except that segment 3 of P2, P3 and P4 exopod has only two spine-like external setae (Figs 11A, B, D, G). Antenna basis without seta (cf. male), exopod with five plumulose setae and one finely serrulate spine-like seta, geniculate setae on endopod with plain terminal segment, terminal claw with fine comb (Fig. 10A). Mandible (Fig. 10B), maxillule endopod with six setae (Fig. 10E), maxilla (Fig. 10F), coxae of maxillipeds touch in midline, basis with fimbriate process (Fig. 10C). First segment of P1 exopod with crescent of denticulate setules (Fig. 10D, left side), first segment of endopod broad ( $l/w = 1.1$ ), area of denticulate setules at lateral end of fimbriate crescent, first claw on terminal segment comb-like with recurved teeth, second claw lamelliform (Fig. 10D). Serrulate spinous seta on segment 3 of P2 endopod more than  $\frac{1}{2}$  length of endopod (0.6:1, Fig. 11G). Serrate spinous seta on segment 2 of P3 endopod  $\frac{2}{3}$  length of endopod (Fig. 11A), large serrate spinous seta on segment 3 longer than endopod (1.38:1). P4 (Fig. 11D) seta on endopod segment 2 and first internal seta of segment 3 plain spinous. P5 exopod (Fig. 9C, 11E) broad, lanceolate with blunt apex, ventral falciform ridge terminates in a deep indentation or notch that appears to fit round the end of the caudal ramus on some specimens (Fig. 9C), medial edge of P5's dorsal expansion overlaps genital double-somite extensively, ventral expansion absent, only one sub-terminal dorsal seta present, dorsal pits absent from P5, lateral border with double row of setules (ventral row of triangular setules and dorsal row of short filiform setules (Fig. 11F). Females carry four large eggs.

**Adult males** (Fig. 12F; Plate 1H, p. 163). Colour lemon yellow. Outline of cephalosome a truncated hemi-ellipse, deeply concave anteriorly with small medial bulge. Cephalosome unusually long ( $\frac{2}{3}$  body length). Posterior region of body (metasome plus genital double-somite with P5s) semicircular. Epipleural lobes of third metasome segments very long, they wrap round P5s plus caudal rami and extend back as far as the posterior limit of the body (Fig. 12F, H). Rostrum not keeled ventrally, dorsal pits and hyaline border (Fig. 12E) as for female. Caudal rami (Fig. 12A) not fused to anal segment, more or less rectangular, medial edge concave leaving an opening between the rami, lateral edge slightly convex, posterior border straight. T1 absent,  $\gamma$  seta recessed at lateral corner, T2 and T3 small, very close together, T4 at medial corner, fringe of short setules along posterior border between T3 and T4. Limbs as described for female except for the following differences. First segment of antennule with pinnate seta (Fig. 12B), second segment short, very narrow posteriorly (Fig. 12D), segment 3+4 unusually long ( $> \frac{1}{2}$  total length of antennule), ventral process or blade present, two small tooth-like and one rounded coupling denticle present on segment 4 (Fig. 12G), no denticulate pad or brush-pad present, aesthetasc and  $\sigma$  seta short (about length of segment 3+4), dactylus broad,

very short ( $\frac{1}{4}$  length of segment 3+4). Antenna with seta at distal end of basis (Fig. 10A, (absent in female). P1 as for female, P2 with two plumose terminal setae on endopod (Fig. 11B), P3 similar to female but terminal serrate seta on endopod is S-shaped and equal to length of endopod (Fig. 11C). P5 baseoendopod fused with metasome segment 4 and genital double-somite. Exopod of P5 appears to articulate with fused genital somite (Fig. 12H), exopod ovate with one plain lateral seta half way down lateral edge (Fig. 12C) and row of 15+ ventral setules, two microscopic spinules (representing atrophied terminal setae) near apex (Fig. 12C). Spermatophore very small (Fig. 12F).

**Etymology.** *Synurus ctenocheirus* has been named from the unique condition of the first terminal comb-like seta on P1 endopod. In all other members of the Porcellidiidae both claws are lamelliform, Harris and Robertson (1994), but in adult and late stage copepodids of this species the first claw is comb-like (*G. ctenos* = a comb + *cheiros* = hand).

**Remarks.** *Synurus ctenocheirus* is remarkable for four unique sexually dimorphic features: presence of a seta on basis of male antenna, epipleural lobes of male metasomal segment 3 that extend back to the same level as the P5 limbs, fusion of male M4 with genital double-somite and P5 baseoendopod, and fusion of female caudal rami with the anal segment.

Animals named *Porcellidium unicus* by Ummerkutty (1970), although not fully described, clearly belong to the genus *Synurus* by virtue of the oval male P5 with atrophied setae, only two external setae on P2, P3 and P4 exopod segment 3, and the fusion of male genital double-somite with P5 baseoendopod and M4, but these features exclude the species from *Porcellidium*. It should be renamed *Synurus unicus* (Ummerkutty, 1970) comb. nov.

The following characters distinguish *S. unicus* from *S. ctenocheirus*. It is larger (female 0.75 mm, male 0.63 mm), Hicks' index for  $\beta$  is 50%, the distance between  $\alpha$  and  $\beta$  setae is  $\frac{1}{2}$  ramus length and the female caudal ramus is not fused to the anal segment. The male P5 is described as pentagonal bordered with setules on lateral edge as far as the lateral seta and there are three atrophied terminal setae. *Synurus unicus* was collected from algae off Vedalai in the Gulf of Mannar, Sri Lanka.

**Distribution.** The type series GI2,9/73 (comprising 44 ♀♀, 30 ♂♂ + 23 juveniles) was collected from *Zostera capricornia* growing on coral sand in the sublittoral fringe at Green Island, Great Barrier Reef, Cairns, but it has not been recorded from the southern coast of Queensland (25°S), V. A. Harris, 1973. Specimens of this species collected from Okinawa, Japan (approx. 27°N) in the collection of Yuka Sasaki have been examined by the author. They appear morphologically identical to the Australian material. Their size falls within the range given above (Yuka Sasaki, pers. comm.).

## Genus *Kensakia* Harris & Iwasaki, 1997

*Kensakia* Harris & Iwasaki, 1997: 136.

*Acutiramus*.—Harris & Robertson, 1994: 289.

*Porcellidium*.—Thompson & Scott, 1903: 275; Kim & Kim, 1997: 153; Walker-Smith, 2001: 665; Wells, 2007: 79.

**Type species.** *Kensakia acuta* (Kim & Kim, 1997)

**Diagnosis.** Segment 3 of male antennule with triangular denticle at base of  $\delta$  seta (not comb-like), segment 4 with large pad of hair-like setules (brush-pad) and small distal denticle; adult female genital double-somite cordate, caudal ramus trapezoid, terminal seta T1 present, T2 absent from female but present on male caudal ramus, T3 absent from both male and female; ventrolateral band of surface markings on underside of cephalosome; maxillule endopod with six setae; coxal lobes of maxillipeds touch in midline; spermatophore elongate, ephemeral on female.

**Species composition.** *Kensakia acuticaudata* (Thompson & Scott, 1903) comb. nov.; *Kensakia acuta* (Kim & Kim, 1997); *K. shimodensis* Harris & Iwasaki, 2009; *K. parva* Harris & Iwasaki, 2009; *K. australis* sp. nov.

The genus has a wide range. It is represented in Japanese and Korean waters, southern Gulf of Thailand, North East coast of Australia, Sri Lanka and the Suez Canal.

**Etymology.** The specific name refers to the pointed shape of the caudal rami (Japanese, *Kensaki* = point of a sword).

**Remarks.** The genus was first defined to accommodate a single species from Kadonohama Bay, Iwate Prefecture, Japan, Harris & Iwasaki (1997). Since then three closely related species have been collected from Japan, Malaya and Australia which share the same unique set of characters and justify admission to the genus.

The characteristic brush-pad of male *Kensakia* differs from the denticulate pad described for genera such as *Murramia* or *Porcelloides* because it is only attached to the

antennule by its proximal edge. It is possible to lift it up as a flap (see Figs 13I). It is the most conspicuous apomorphic character defining the genus. Markings on the under surface of the cephalosome (see Fig. 13I, left figure) may form a band parallel to the hyaline border (ventrolateral band). It has been found on all species examined. This band is structurally different from the condition in *Tectacingulum* because it does not involve displacement of the hyaline membrane or its sensilla.

The diagnostic characters listed above clearly separate members of *Kensakia* from other superficially similar genera (i.e., *Ravania*, *Acutiramus* and *Porcelloides*).

Female specimens in the NHM collection labelled *Porcellidium acuticaudatum* Thompson & Scott 1903 (1928, 4,2,43), collected from Lake Timsâh, Ismalia, by the Cambridge University Expedition to the Suez Canal, Gurney (1924), were examined by the author. Females have a trapezoid caudal ramus, but T2 and T3 are missing which eliminates them from *Porcelloides*. They also have a distinct notch at the posterior end of the falciform ridge on P5 (compare with Fig. 14A). These are all characteristics of *Kensakia* and eliminate *P. acuticaudatum* from *Porcellidium*, *Acutiramus* and *Ravania*. Unfortunately, details of the male antennule, which would have confirmed that *P. acuticaudatum* belongs to *Kensakia*, could not be resolved on the specimen examined, however the male cephalosome is only slightly truncated with broadly rounded shoulders as in *K. australis*. Illustration of the male by Gurney (1927) lacks important detail, but P5 is shown trapezoid and P2 has two terminal setae on endopod. This suggests that the species should be renamed *Kensakia acuticaudata* (Thompson & Scott, 1903) comb. nov. Thompson & Scott found three female specimens in washings from Muttuvaratu pearl oysters, Sri Lanka (formerly Ceylon), but material from Ismalia was washed from *Sargassum* sp., and *Halophila* sp., Gurney (1927). The species is described as "...vivid rosy red or red spots on thorax and abdomen", Gurney (1927).

### Key to species of *Kensakia*

*Kensakia acuticaudata* (Thompson & Scott, 1903) has not been included in this key due to lack of data on male characters.

- 1 Numerous dorsal sensilla on cephalosome (>200). Distal coupling denticle on segment 4 of male antennule relatively large (10–15  $\mu$ m) ..... *Kensakia shimodensis* Harris & Iwasaki, 2009
- Dorsal sensilla not numerous (< 50). Distal coupling denticle on segment 4 of male antennule small (5  $\mu$ m) ..... 2
- 2 Male P5 curved, not trapezoid. Male rostrum U-shaped in ventral view. Ventrolateral band on cephalosome not net-like ..... *Kensakia parva* Harris & Iwasaki, 2009
- Male P5 trapezoid. Male rostrum V or Y-shaped in ventral view. Ventrolateral band on cephalosome net-like ..... 3
- 3 Female maximum length < 0.65 mm. Female cephalosome width/rostrum ratio < 4.2. Labrum with pad of minute setules + four lateral striations. Female carries eight eggs. (Plate 1D) ..... *Kensakia australis* sp. nov.
- Female maximum length > 0.75 mm. Female cephalosome width/rostrum ratio > 4.5. Labrum without pad of fine setules or striations. Female carries 16–18 eggs. (Plate 2F) ..... *Kensakia acuta* (Kim & Kim, 1997)



***Kensakia australis* sp. nov.**

Figs 13, 14; Plate 1D

**Type material.** HOLOTYPE adult male, length 0.55 mm, P81210. ALLOTYPE adult female, length 0.62 mm, P81211. PARATYPE specimens P81212 (10 ♀♀, 5 ♂♂) deposited at AM, Sydney. Additional paratypes deposited at NHM, London. All collected from a brown seaweed, *Zonaria* sp., sublittoral fringe, Point Vernon, Hervey Bay, Queensland (25°15'S 152°47'E), V. A. Harris 1997.

**Diagnosis.** Labrum with medial pad of minute setules plus four or five lateral striations (ridge-plates absent); female rostrum broad ( $W/R = 4.1$ ); females carry eight eggs; male antennule with transverse tunnel-like thickening of cuticle on ventral side of segment 4 (Fig. 13E), distal coupling denticle very small (3–5 µm), dactylus long (= length of segment 3+4), hooked distally; ventrolateral band on ventral side of cephalosome with net-like markings; very few dorsal sensilla; no setae lateral to female genital opening; male rostrum V-shaped ventrally;  $\alpha$  and  $\beta$  setae on male caudal ramus short ( $\frac{1}{2}$  width of ramus); ventral setules on male anal segment; dorsal setae on female P5 not pinnate.

**Biometric data.** *Females* (N = 25): maximum length ( $L_{\max}$ ) mean 0.615 mm, range 0.58–0.65 mm, body length ( $L_{\text{urs}}$ ) mean 0.58, range 0.56–0.61 mm; cephalosome width (W) mean 0.37 mm; rostrum (R) width 0.09 mm; genital double-somite width 0.186 mm, length 0.145 mm; caudal ramus maximum width 0.05 mm, length 0.135 mm,

Ratios:  $L_{\text{urs}}/W$  1.57,  $L_{\max}/W$  1.66;  $W/R$  4.1; genital double-somite w/l 1.27, arch 55% of length; caudal ramus 22% of  $L_{\text{urs}}$ , l/w 2.6, Hicks' index for  $\alpha$  88%, for  $\beta$  76%, apex angle of ramus 42°.

*Males* (N = 23): maximum length ( $L_{\max}$ ) mean 0.55 mm, range 0.55–0.58 mm, body length ( $L_{\text{urs}}$ ) mean 0.51, range 0.49–0.64 mm; cephalosome width (W) mean 0.34 mm, range 0.31–0.37 mm, length 0.32 mm; rostrum length 0.045 mm; caudal ramus width 0.04, length 0.05 mm; antennule (fully extended) 0.145 mm; spermatophore  $0.078 \times 0.02$  mm.

Ratios:  $L_{\text{urs}}/W$  1.5,  $L_{\max}/W$  1.6; cephalosome 58% of  $L_{\max}$ ; caudal ramus l/w 1.25; antennule 26% of body length  $L_{\text{urs}}$ , segments 3+4 41%, dactylus 43%, aesthetasc 70% of antennule length; spermatophore 14% of  $L_{\text{urs}}$ .

**Description.** *Adult females* (Fig. 13A; Plate 1D, p. 163): colour pale yellow or colourless, mid-dorsal area of cephalosome, metasome and genital double-somite dark blue-purple, caudal rami and P5s not coloured. Cephalosome semicircular, rostrum broad, not prominent, dorsal pits on cephalosome, metasome, genital double-somite and P5 exopod small (3–5 µm), very few dorsal sensilla. Hyaline border clear, 6–7 µm wide. Ducts of marginal glands open dorsally. On ventral side of cephalosome there is a broad lateral band of net-like markings about 30 µm wide that narrows posteriorly (ventrolateral band, Fig. 13J) and a peripheral band of vacuous cells (seen from ventral side Fig. 13H). Some specimens have reticulate markings on ventral surface of the rostrum. Labrum (Fig. 14J) with pad of minute hair-like setules and a group of four or five setules laterally, but no ridge plates. Genital double-somite (Fig. 14C)

narrow (50% of cephalosome width), lateral border with fine setules, small notch marks boundary between anterior and posterior lobes, posterior lobe pointed posteriorly, arch deep, no anterolateral ridges (rugosities) present. Sternal sclerite of metasome segment 4 with fimbriate posterior border, genital opening narrow (35 µm), no seta at lateral corner of opening. Caudal ramus (Figs 13D) trapezoid (sides slightly divergent), maximum width  $\frac{2}{3}$  down ramus, lateral and medial edges without setules, dorsal surface with net-like pattern.  $\alpha$  and  $\beta$  setae close, terminal setae T1 and T4 plain, very small, setae T2 and T3 absent, posterior border with very short, fine setules. Structure and setation of mouthparts and ambulatory limbs typical of family. Antenna basis with triangular setules along anterior edge but no setules on lateral surface (Fig. 14B), exopod with five plumulose setae and one plain spinous seta, fine border setules on segment 1 of endopod, segment 2 with three lateral setae, end segment of geniculate setae plain, long thin comb-like claw ( $> \frac{1}{2}$  length of endopod segment 2). Mandible, maxillule and maxilla as shown in Figs 14G, I and K respectively, maxilliped (Fig. 14L) basis with fimbriate border but no rows of small lateral setules. P1 (Fig. 13C) with coxal seta, inconspicuous small patch of denticulate pegs at lateral end of fimbriate crescent. Serrulate spinous seta on segment 2 of P3 endopod (Fig. 14E) shorter than endopod (0.8:1), large serrate spinous seta on segment 3 much longer than endopod (1.5:1). P4 endopod with serrulate spinous seta on segment 2 and 3 (Fig. 14D). Exopod of P5 lanceolate, without ventral expansion, dorsal surface pitted, apical end of ventral falciform ridge with concave notch (Fig. 14A), border setules short, two prominent dorsal setae and two apical setae. P5s extend beyond genital double-somite and caudal rami but do not touch posteriorly. Females carry eight eggs.

*Adult males* (Fig. 13B). Colour similar to female except that the blue-purple dorsal area does not extend beyond metasome segment 2. Cephalosome truncated with sloping, rounded shoulders, lateral angle of antennule socket prominent. Rostrum narrow, keeled and Y-shaped in ventral view, width  $\frac{2}{3}$  of length (Fig. 14M). Dorsal pits, hyaline border, vacuolated cells, reticulate ventral band and labrum as for female. Caudal rami (Fig. 14H) rectangular, slightly longer than wide (1.2:1), dorsal surface with net-like markings,  $\alpha$  and  $\beta$  setae short ( $< \frac{1}{2}$  width of ramus). Setae T1, T2 and T4 very short and small (T2 and T4 lost on many specimens), T3 absent. Posterior border with very short setules. Small group of striations (5 or 6) on ventral side of anal segment at the posterolateral corner (Fig. 14H). Antennule (Fig. 13F) with pinnate seta on segment 1, distal coupling denticle on segment 4 small (3–5 µm) bicuspid, close to brush-pad, aesthetasc almost as long as segment 3+4 + dactylus with two characteristic constrictions, dactylus equals length of segment 3+4, hooked at tip (Fig. 13F, G). A tunnel like indentation of the ventral cuticle is found on the ventral side of segment 4 just proximal to the sensory lobe carrying aesthetasc (Fig. 13E, “tunnel”). Limbs as for female except that P2 has only two terminal setae on the endopod. All setae on P4 endopod plumose. P5 exopod trapezoid, lateral seta with row of 12–15 ventral setules and of different shape to terminal setae (Fig. 14F). Spermatophore very small.

**Etymology.** The first species belonging to *Kensakia* recorded from Australia.

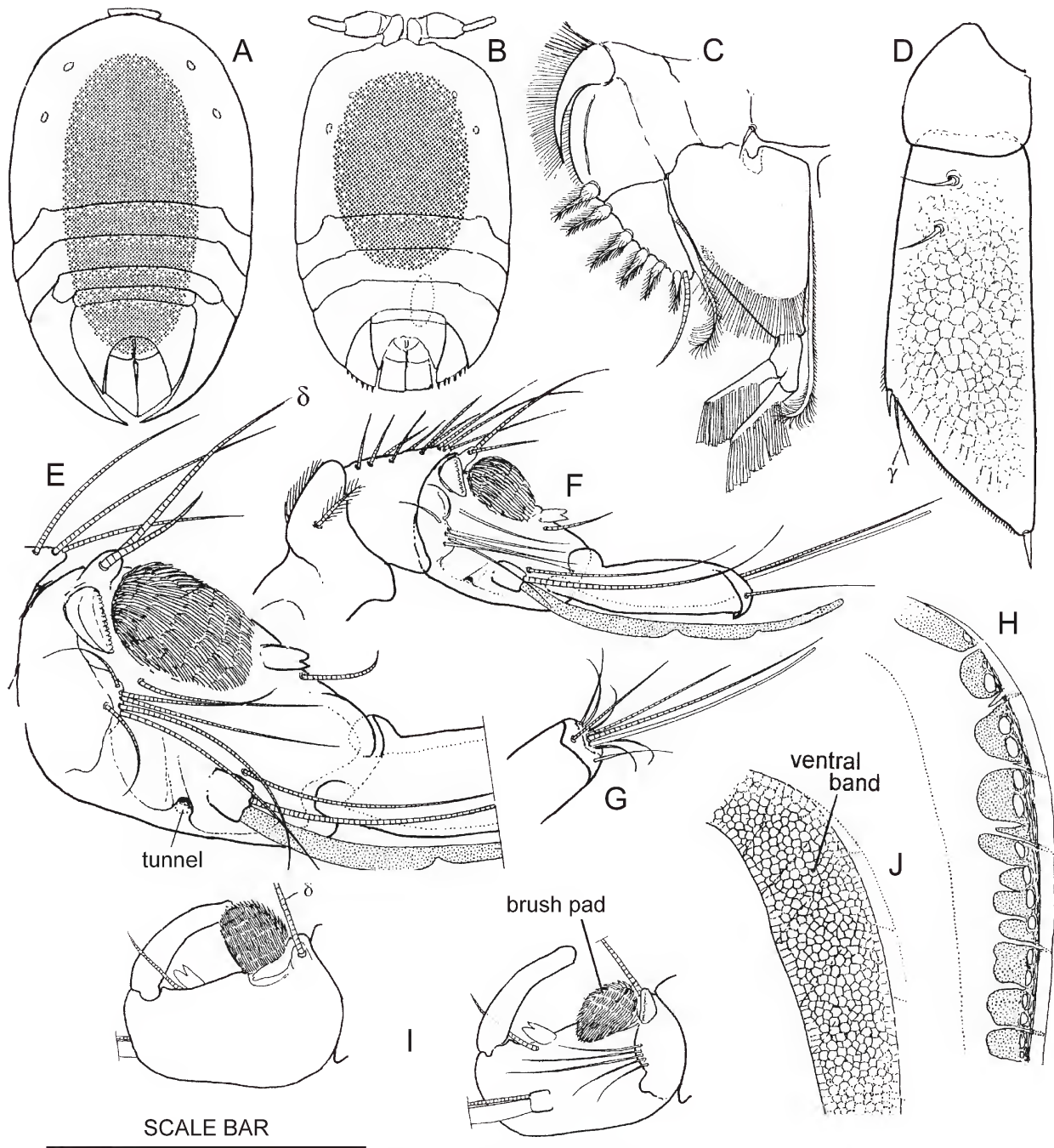


Figure 13. *Kensakia australis* sp. nov. Female: (A) adult; (C) P1; (D) caudal ramus. Male: (B) adult; (E) antennule (ventral, showing "tunnel"); (F) antennule; (G) antennule segment 6; (H) cephalosome border showing vacuolated cells; (I) antennule brush pad (dorsal, ventral); (J) underside of cephalosome showing ventrolateral band. Scale bar: A, B = 0.48 mm. C = 0.12 mm. D, F, I = 0.11 mm. E, G = 0.05 mm. H, J = 0.10 mm.

**Remarks.** *Kensakia australis* closely resembles Japanese specimens of *K. acuta* but is significantly smaller, differs slightly in colour pattern, shape of female rostrum and in the number of eggs carried in each brood.

**Distribution.** *Kensakia australis* is common at low water spring tides at Hervey Bay, Queensland on *Zonaria* sp. Type series (PV3, 7/97, 76 ♀♀ + 65 ♂♂) and *Eucheuma* sp., (PV6, 60 ♀♀ + 23 ♂♂ + juveniles), V. A. Harris 1997. It has also been recorded from *Dilophus* sp., and *Lobophora* sp., in rock pools at Arrawarra, NSW (30°03'S 153°02'E), V. A. Harris, 1982.

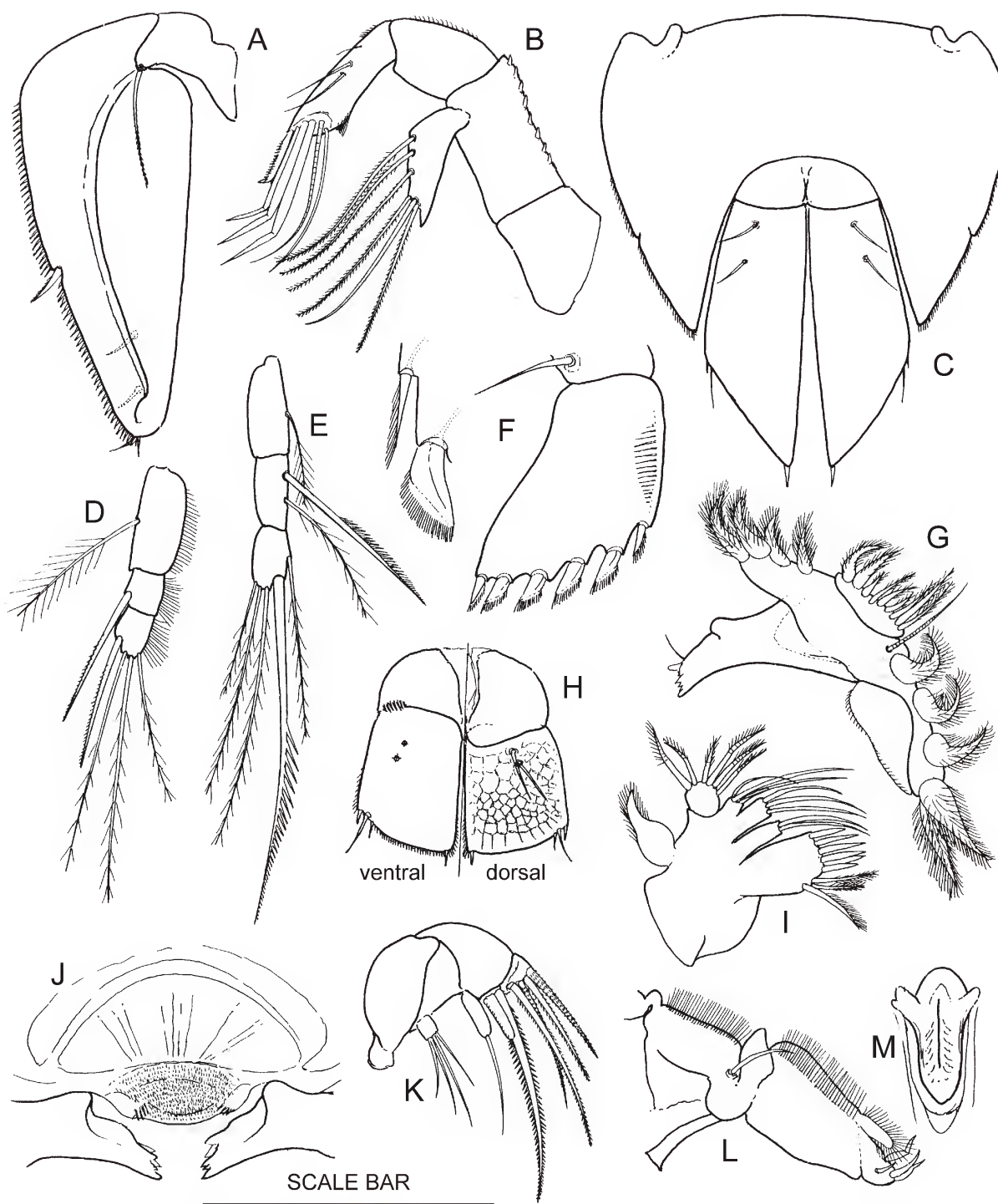


Figure 14. *Kensakia australis* sp. nov. Female: (A) P5 (ventral); (B) antenna; (C) genital double-somite and caudal rami; (D) P4 endopod; (E) P3 endopod; (G) mandible; (I) maxillule; (J) labrum; (K) maxilla; (L) maxilliped. Male: (F) P5 (ventral, detail of lateral and terminal setae); (H) caudal rami and anal segment; (M) rostrum (ventral). Scale bar: A, B = 0.18 mm. C = 0.14 mm. D, I, J, K, L = 0.08 mm. E, F, H = 0.1 mm. G = 0.12 mm.



## Genus *Kushia* Harris & Iwasaki, 1996

*Kushia* Harris & Iwasaki, 1996: 204.—Bodin, 1997: 68; Walker-Smith, 2001:655; Wells, 2007: 80.

*Porcellidium*.—Gamô, 1969: 345; Kim & Kim, 1997: 161.

**Type species.** *Kushia zosteraphila* Harris & Iwasaki, 1996.

**Diagnosis.** Female P5 exopod with ventral expansion that lies under (ventral to) edge of genital double-somite (Fig. 16E); male antennule with conspicuous anterior comb near  $\delta$  seta on segment 3, and three coupling denticles on segment 4 (middle denticle expanded distally, Y-shaped Fig. 18E, F), no brush-pad; hyaline border with sensilla at lateral edge of cephalosome, marginal glands conspicuous with ducts opening dorsal to border; no massive dorsal cuticular honeycomb; no ridge-plates on labrum; no lateral striations on female genital double-somite; female caudal rami pentagonal, typically widen posteriorly, terminal setae T1 to T4 all present, not pinnately clavate or evenly spaced;

maxillule endopod with six setae; coxae of maxillipeds touch in mid-line; male P5 trapezoidal with six terminal setae; spermatophore elongate, ephemeral on female.

**Species composition.** *Kushia zosteraphila* Harris & Iwasaki, 1996; *K. gamoi* Harris & Iwasaki, 1996; *K. igaguria* Harris & Iwasaki, 1996; *Kushia spathoides* sp. nov.

The genus is known from Japan, Korea and northern NSW, Australia.

**Etymology.** The name *Kushia* refers to the characteristic anterior comb on male antennule, (Japanese *Kushi* a type of Japanese hair comb).

**Remarks.** The genus is clearly defined by structure of male antennule and female P5 limb. The marginal glands possessed by all members of the Porcellidiidae are particularly conspicuous in the above four species. They also occur in other parts of the body such as the genital double-somite, caudal rami and P5 limbs.

### Key to the species of *Kushia*

- 1      Hyaline border of cephalosome clear (not striated). Male cephalosome sharply truncated with angular shoulders ..... 2
- Hyaline border with striations. Male cephalosome not sharply truncated, shoulders smoothly rounded. (Plate 11, p. 163) ..... *K. spathoides* sp. nov.
- 2      First dorsal seta on female P5 very small or absent. Truncated anterior of male cephalosome straight. No setules at base of terminal setae on male P5 ..... 3
- First dorsal seta on female P5 long, (same length as seta two & three). Truncated anterior of male cephalosome concave. Rows of 7–10 setules at base of each terminal seta on male P5. (Plate 2D, p. 165) ..... *K. zosteraphila* Harris & Iwasaki, 1996
- 3      Female caudal ramus with parallel sides\*. Proximal denticle on segment 4 of male antennule flat with serrated edge. Colouration uniform pale orange-brown ..... *K. gamoi* Harris & Iwasaki, 1996
- Female caudal rami widen posteriorly\*. Proximal denticle on segment 4 of male antennule rounded and covered with spine-like setules. Colouration pale yellow-brown with metasome and genital double-somite darker orange-brown. (Plate 2C, p. 165) ..... *K. igaguria* Harris & Iwasaki, 1996

\* Caudal ramus laid flat.

### *Kushia spathoides* sp. nov.

Figs 15–18, Plate 11

**Type material.** HOLOTYPE adult male, length 0.68 mm, P81204; ALLOTYPE adult female, length 0.75 mm, P81205; PARATYPE specimens, 5 ♀♀, 5 ♂♂, P81206, deposited at AM, Sydney. Additional paratypes deposited at NHM, London. All collected at Arrawarra Headland, Woolgoolga, northern NSW, Australia (30°06'S 153°02'E), washed from *Caulerpa vesiculifera* in coral rockpool, V. A. Harris, 1982.

**Diagnosis.** Striations in hyaline border close to edge of cephalosome (Fig. 15E); male cephalosome rounded anteriorly (very slight truncation), shoulders smoothly rounded; anterior comb on male antennule short (length about twice width), small finger-like ventral process lies

between anterior comb and  $\pi$  setae on segment 3 of male antennule (Fig. 18F), proximal coupling denticle on segment 4 flat with serrate edge, middle denticle Y-shaped with plain edge, dactylus not bent or hooked distally; female caudal ramus widens posteriorly, T1 recessed at lateral corner to give ramus pentagonal appearance; dorsal seta 1 on female P5 exopod very small, seta 2 large (Fig. 16D).

**Biometric data.** *Females* (N = 10): maximum length ( $L_{\max}$ ) mean 0.75 mm, range 0.72–0.76 mm, body length ( $L_{\text{urs}}$ ) mean 0.71 mm, range 0.69–0.72 mm; cephalosome width (W) mean 0.48 mm, range 0.45–0.51 mm; rostrum (R) 0.095 mm; genital double-somite width 0.27 mm, length 0.20 mm; caudal ramus width (mean) 0.055 mm, length 0.11 mm.

Ratios:  $L_{\text{urs}}/W$  1.46,  $L_{\max}/W$  1.54; cephalosome  $W/R$  5.1; genital double-somite  $w/l$  0.73, arch 40% of length; caudal ramus 15% of  $L_{\text{urs}}$ ,  $l/w$  2.0, Hicks' index for  $\alpha$  73%, for  $\beta$  55%.

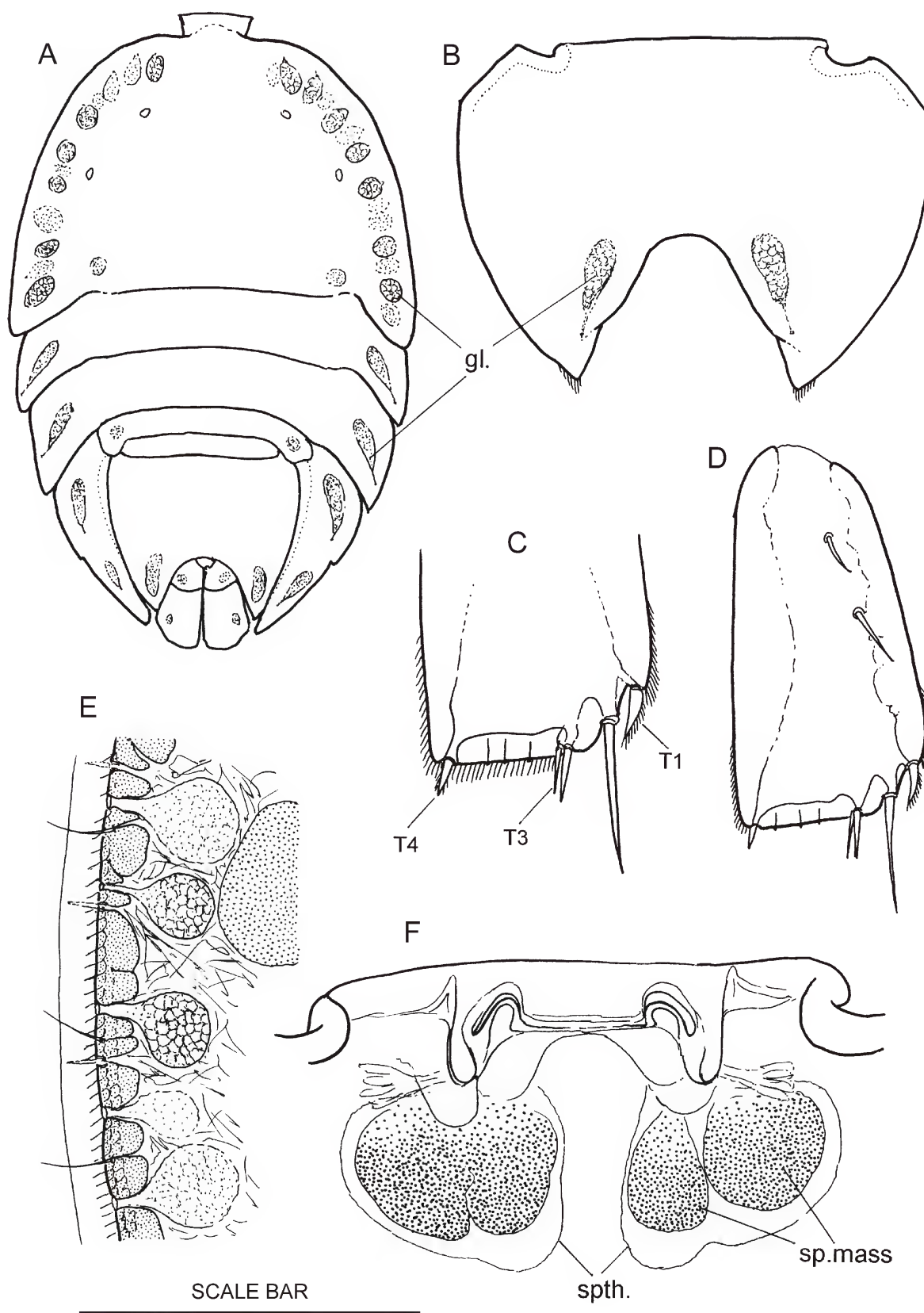


Figure 15. *Kuschia spathoides* sp. nov. Female: (A) adult showing distribution of marginal glands (*gl.* marginal glands); (B) genital double-somite; (C, D) caudal ramus; (E) edge of cephalosomite showing striations; (F) genital opening showing spermathecae (*spth.*) and sperm mass (*sp. mass*). Scale bar: A = 0.45 mm. B, D, E, F = 0.1 mm. C = 0.06 mm.

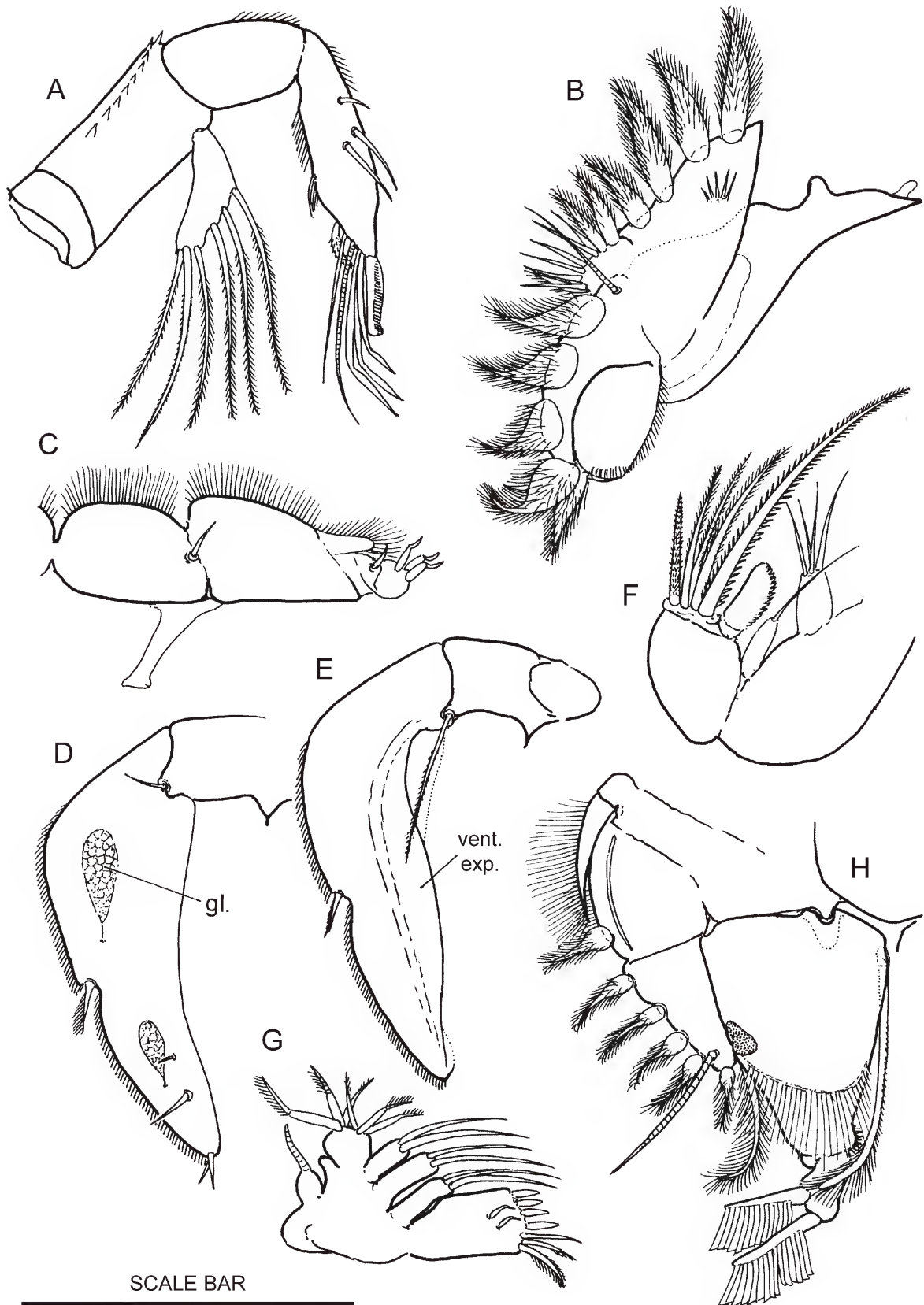


Figure 16. *Kushia spathoides* sp. nov. Female: (A) antenna; (B) mandible; (C) maxilliped; (D) P5 (dorsal, *gl.* marginal glands); (E) P5 (ventral, showing ventral expansion, *vent. exp.*); (F) maxilla; (G) maxillule; (H) P1. Scale bar: A = 0.08 mm. B = 0.2 mm C = 0.09 mm. D, E = 0.18 mm. F, H = 0.12 mm. G = 0.1 mm.



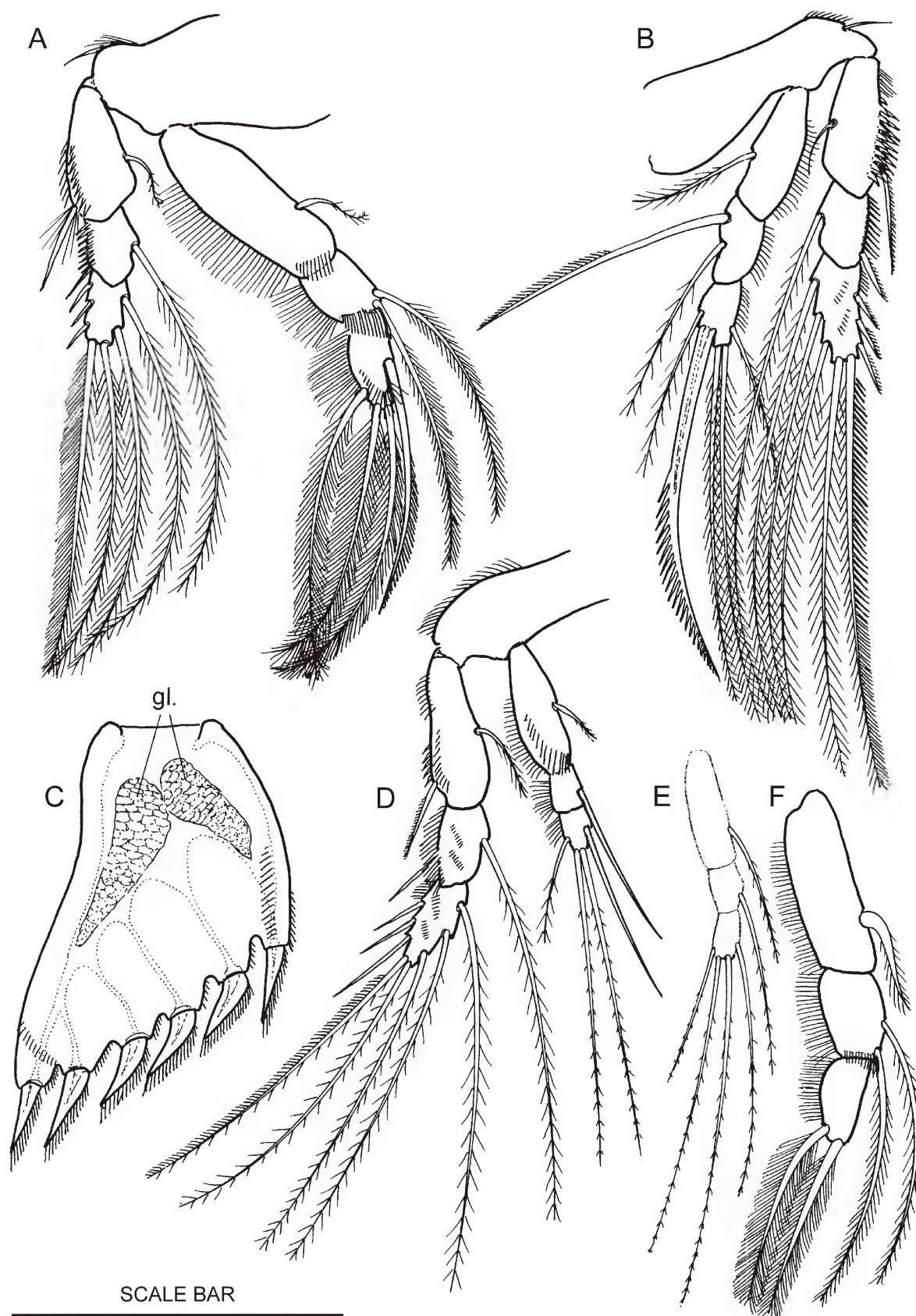


Figure 17. *Kushia spathoides* sp. nov. Female: (A) P2; (B) P3; (D) P4. Male: (C) P5 (ventral, *gl.* marginal glands); (E) P4 endopod; (F) P2 endopod. Scale bar: A, B, D, E, F = 0.14 mm. C = 0.1 mm.

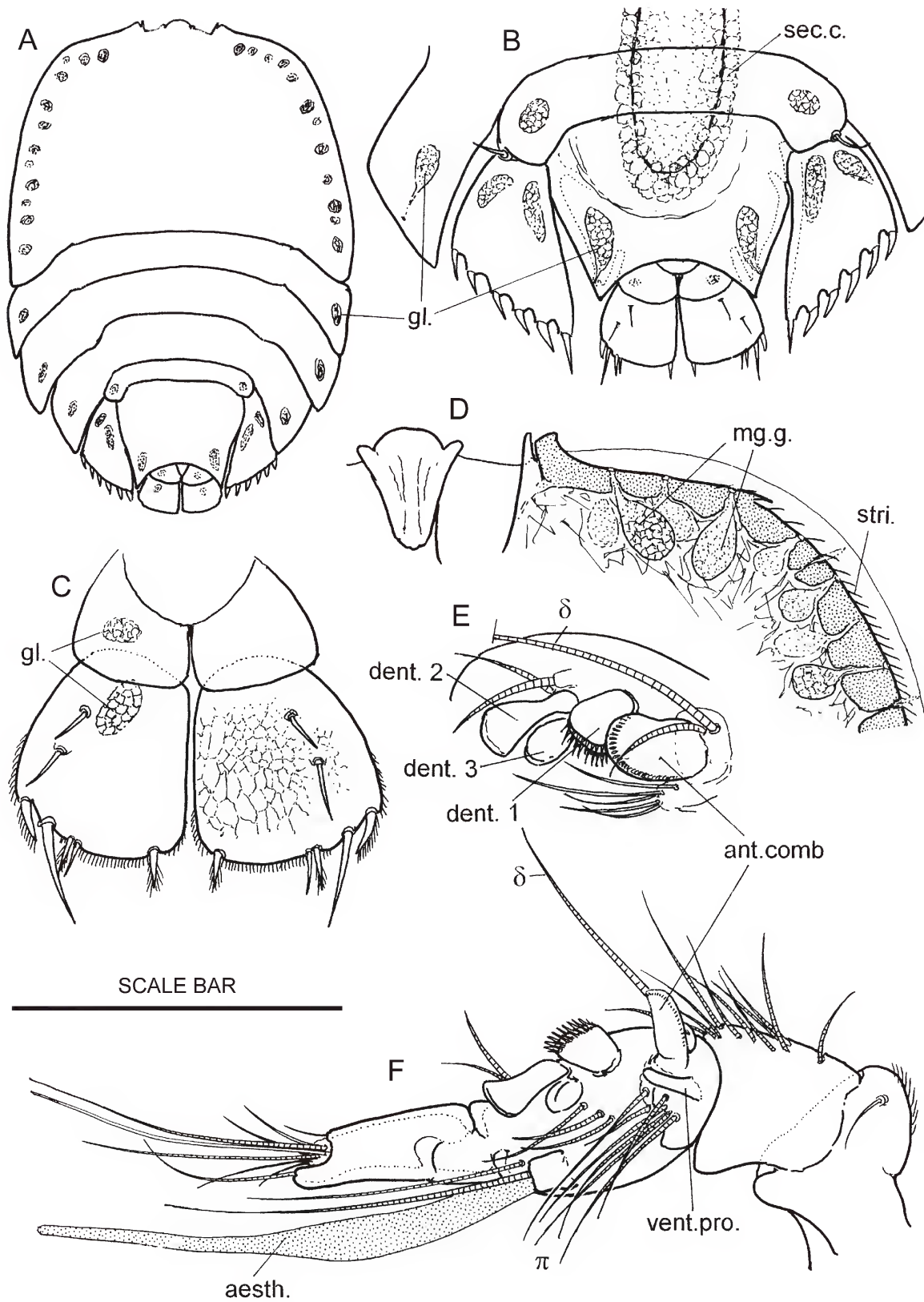


Figure 18. *Kushia spathoides* sp. nov. Male: (A) adult (gl. marginal glands); (B) abdominal region and caudal rami showing secretory cells (sec.c.) producing spermatophore case; (C) caudal rami; (D) rostrum and "shoulder" (ventral; mg.g. marginal gland; stri. striations); (E) coupling denticles (dent.) of antennule; (F) antennule, showing anterior comb (ant.comb) and ventral process (vent.pro.). Scale bar: A = 0.45 mm. B = 0.23 mm. C, F = 0.1 mm. D = 0.14 mm. E = 0.08 mm.

**Males** (N = 7): maximum length ( $L_{\max}$ ) mean 0.68 mm, range 0.66–0.70 mm, body length ( $L_{\text{urs}}$ ) mean 0.63 mm, range 0.62–0.67 mm; cephalosome width (W) mean 0.46 mm, range 0.43–0.47 mm, length 0.35 mm; caudal ramus width 0.05 mm, length 0.05 mm; antennule (fully extended) 0.19 mm, length of anterior comb on antennule 0.02 mm; spermatophore  $0.23 \times 0.07$  mm.

Ratios:  $L_{\text{urs}}/W$  1.38,  $L_{\max}/W$  1.47, cephalosome 52% of  $L_{\max}$ ; caudal ramus l/w 1.0; antennule 28% of body length; segment 3+4 40%, dactylus 33% of antennule length; spermatophore 34% of  $L_{\max}$ .

**Description.** *Adult females* (Fig. 15A; Plate 1I, p. 163): colour pink. Body outline elliptical, rostrum prominent, narrow. Dorsal pits conspicuous (4–6  $\mu\text{m}$ ), hyaline border (8  $\mu\text{m}$  wide) appears striated due to edge of overlapping pits that project about 4  $\mu\text{m}$  over hyaline border (Fig. 15E, 18D). Twelve or more conspicuous marginal glands on each side of the cephalosome with ducts that open just above hyaline border (Figs 15A,E, 18A,D). Similar glands are found in the epipleura of metasome segments, genital double-somite, caudal rami and P5 limbs. Dorsal surface of genital double-somite with pits, lateral border smoothly curved without notch or scar to indicate boundary between anterior and posterior lobes, border setules absent except for a few short setules at pointed posterior extremity, arch less than half length of genital double-somite (Fig. 15B). Genital opening as shown in Fig. 15F. Labrum without ridge plates. Caudal rami (Fig. 15D) widen posteriorly (maximum width about  $\frac{4}{5}$  down ramus), dorsal surface with faint reticulation. Beta seta almost half way down ramus,  $\gamma$  seta slightly recessed on posterior border, T1 recessed at lateral corner, T2 and T3 setae extremely close, T4 short at medial corner, posterior border thickened with three dorsal ridges (Fig. 15C), fine setules along posterior border. Structure and setation of mouthparts and ambulatory limbs typical of family. Antenna (Fig. 16A) basis with diagonal row of triangular setules, marginal setules on segments 1 and 2 of endopod, exopod with five finely plumulose setae and one spinous seta, three lateral setae on segment 2 of endopod, geniculate setae with plain terminal section, small sensory structure present, claw comb-like. Mandible (Fig. 16B) with small group of setules on anterior lobe of palp. Maxillule (Fig. 16G) with single seta on exopod. Maxilla and maxilliped as in (Fig. 16F, C). P1 endopod segment 1 narrow (l/w = 1.28), (Fig. 16H) with small triangle of denticulate setules at lateral corner of fimbriate crescent. Serrulate spinous seta on segment 3 of P2 endopod  $\frac{3}{4}$  length of endopod (Fig. 17A). Serrulate spinous seta on segment 2 of P3 endopod (Fig. 17B) equal in length to endopod (1:1), large serrate spinous seta on segment 3 longer than endopod (1.35:1). Endopod of P4 with a plain spinous seta on segment 2 and similar first internal seta on segment 3 (Fig. 17D). Baseoendopod of P5 with triangular prominence on posterior border (Fig. 16D), exopod lanceolate, dorsal surface with pits, ventral expansion below falciform ridge (Fig. 16E) lies under edge of genital double-somite, first dorsal seta very small or absent, second seta long, apex with two setae. Females carry 12 eggs.

*Adult males* (Fig. 18A). Colour pink. Anterior of cephalosome rounded, only slightly truncated, shoulders smoothly rounded, lateral angle of antennule socket prominent. Hyaline border, marginal glands and border striations as for female (Fig. 18D). Caudal rami (Fig. 18C)

widen posteriorly (maximum width almost twice proximal width), lateral and posterior border convex, length equal to maximum width, dorsal surface with faint reticulate pattern. Setation similar to female, but posterior border without three dorsal ridges. Antennule (Fig. 18F), anterior comb on segment 3 broad (spatulate), small finger-like ventral process present between anterior comb and  $\pi$  setae. First coupling denticle flat with double row of serrations along edge, second denticle longer, widens distally, without serrated edge, third denticle circular without serrated edge (Fig. 18E). Dactylus straight,  $\frac{3}{4}$  length of segment 3+4, no terminal hook. Aesthetasc very long (about  $\frac{3}{4}$  length of antennule). Limbs as described for female except for the following differences. P2 with two plumose terminal setae on segment 3 of endopod (Fig. 17F). Terminal spinous seta on P3 endopod equal in length to endopod. P4 endopod setae not spinous (Fig. 17E). P5 trapezoid (Fig. 17C), dorsal surface with pits, about 15 fine ventral setules at base of first (lateral) seta, diagonal row of five or six setules at base of each terminal seta. Spermatophore large ( $\frac{1}{2}$  body length). Cells secreting spermatophore capsule shown in Fig. 18B.

**Etymology.** The trivial name, *spathoides*, refers to the broad spatulate anterior comb on segment 3 of the male antennule (G. *spathe* = ladle or spatula + *oides* = shape). It contrasts with the long narrow comb on Japanese species.

**Remarks.** The genus *Kushia* is known from Japan, but *K. spathoides* is the first record for Australia.

**Distribution.** This species was collected from *Caulerpa vesiculifera* growing in a coral rock pool at Arrawarra Head, NSW, but was not found at Nambucca Heads (60 km south) or Ballina (140 km north). All females in type series, (Aw14,11/82, 42 ♀♀, 41 ♂♂, 26 juveniles) carry eggs, nine of the males were coupled to juvenile females, V. A. Harris 1982.

## Genus *Acutiramus* Harris & Robertson, 1994

*Acutiramus* Harris & Robertson, 1994: 288.—Bodin, 1997: 67.

*Kioloaria* Harris, 1994.—Bodin, 1997: 67.

*Porcellidium*.—Thompson & Scott, 1903: 275; Geddes, 1968: 11; Humes & Ho, 1969: 115; Hicks & Webber, 1983: 439; Ho, 1986: 21; Kim & Kim, 1996: 376; Walker-Smith, 2001: 655; Wells, 2007: 80.

**Type species.** *Acutiramus rufolineatus* Harris & Robertson, 1994: 289.

**Diagnosis.** No anterior comb or denticle near  $\delta$  seta on male antennule segment 3, typically two coupling denticles on segment 4; female caudal ramus typically rhomboid but may taper distally; terminal setae T1 to T4 always present, T4 at posterior apex; six setae on maxillule endopod; coxae of maxillipeds touch in midline; no ventral expansion to female P5, P5 limbs reach beyond genital double-somite and caudal rami to touch one another posteriorly; spermatophore elongate, ephemeral on female.

**Species composition.** Species possessing these features fall into two distinct groups—those living as inquilines or commensals with hermit crabs and those free living on algae.



The commensal group do not have an internal seta on segment 1 of P3 endopod.

*Acutiramus brevicaudatus* (Thompson & Scott, 1903); *A. tapui* (Hicks & Webber, 1983) comb. nov.; *A. paguri* (Ho, 1986) comb. nov.; *A. similis* (Kim & Kim, 1996) comb. nov.; *A. cumulus* sp. nov.; *A. iwasakii* sp. nov.

The algal group have an internal seta on segment 1 of P3 endopod.

*Acutiramus geddesi* (Geddes, 1968) comb. nov. (synonym *Porcellidium ovatum* Geddes, 1968); *A. rufolineatus* Harris & Robertson, 1994; *A. quinquelineatus* Harris & Robertson, 1994; *A. sesquimaculatus* (Harris, 1994) comb. nov.; *A. bipunctatus* sp. nov.; *A. edenensis* sp. nov.

Genus known from Indian Ocean, Madagascar, Ceylon, Pacific Ocean, Japan, Korea, Australia, New Zealand and Bahamas.

**Remarks.** Although no clear apomorphic character defines *Acutiramus*, the genus is clearly separated from *Porcellidium* by a unique combination of characters and is excluded from all other genera by their own apomorphies. Relative to cephalosome width (W), the genital double-somite width (w) of *Acutiramus* is narrower than that of *Porcellidium* (mean w/W for *Acutiramus* = 48%, range 40–53%, N = 10 species; for *Porcellidium* w/W = 62%, range 55–63%, N = 18 species) and the posterior lobe is narrow and pointed compared with the broad, rounded posterior lobe of *Porcellidium* species. A characteristic feature of all female members of the genus is the long P5 limb that extends beyond the posterior limit

of the caudal furca. On living or freshly preserved animals the posterior apices appear to touch, but when mounted on a slide the pressure of the cover glass usually separates them as shown in Figure 27A. *Synurus* and *Kensakia* also have P5 limbs that are longer than the caudal furca and may touch posteriorly, but their defining apomorphic characters eliminate *Acutiramus* species.

*Porcellidium ovatum* Haller, 1879 is a synonym of *Porcelloides tenuicaudus* (see Harris, 2014), but the animals identified by Geddes (1968) as *Porcellidium ovatum* do not show the characteristic features of *Porcelloides tenuicaudus*, i.e., female body shape is oval, not ovoid; caudal ramus rhomboid, not trapezoid; terminal seta T3 is present; genital double-somite is deeply cleft and its arch encloses half the caudal furca; dorsal setae on P5 are plain, not pinnate. Moreover, Geddes' female is less than half the size (0.62 mm compared with 1.4 mm). The shape and setation of the female caudal ramus and length of P5 eliminate Geddes' animals from *Porcellidium* and the presence of T3 eliminates them from *Ravania* and *Kensakia*. They are included here as *Acutiramus geddesi* (Geddes, 1968) comb. nov.

Walker-Smith (2001) argues that the genus *Kioloaria* possesses the same character set as *Acutiramus* except for the number of setae on male P2 limb. This character cannot be considered apomorphic because it occurs sporadically in other genera and so there is no justification for maintaining *Kioloaria*. This argument is accepted, although *K. sesquimaculata* does have an unusual male antennule. It is moved to *Acutiramus* as *A. sesquimaculatus* (Harris, 1994). *Kioloaria* now becomes a junior synonym of *Acutiramus*.

### Key to the species of *Acutiramus*

- 1 No internal seta on segment 1 of P3 endopod. Animals live in association with hermit crabs ..... 2
- Internal seta present on segment 1 of P3 endopod. Animals live on seaweed ..... 6
- 2 Female caudal ramus rhomboid, T2 and T3 close together, wide gap between T3 and T4. Male shoulders rounded ..... 3
- Female caudal ramus not rhomboid, tapers posteriorly, posterior edge rounded, no network of ridges (if present not prominent, restricted to posterior). T2, T3 and T4 evenly spaced. Male shoulders rounded ..... *Acutiramus tapui* (Hicks & Webber, 1983) comb. nov.
- Female caudal ramus rhomboid with conspicuous dorsal network of ridges, T2, T3 and T4 bunched together at apex. Male shoulders prominent ..... *Acutiramus cumulus* sp. nov.
- 3 ¼ or more of caudal ramus enclosed in arch of genital double-somite ..... 4
- Caudal ramus completely excluded from arch of genital double-somite ..... *Acutiramus brevicaudatus* (Thompson & Scott, 1903)
- 4 Number of setae on internal edge of P3 endopod = 0:2:4, P4 endopod = 0:1:3 ..... *Acutiramus paguri* (Ho, 1986) comb. nov.
- Number of setae on internal edge of P3 endopod = 0:2:5, P4 endopod = 1:1:4 ..... 5
- 5 Female rostrum appears concave with straight hyaline border. Male rostrum with conspicuous anterior point. γ seta on male caudal ramus equals width of ramus ..... *Acutiramus iwasakii* sp. nov.
- Anterior border of female rostrum not concave. Male rostrum not pointed anteriorly. γ seta on male caudal ramus twice width of ramus ..... *Acutiramus similis* (Kim & Kim, 1996)

- 6  $\alpha$  and  $\beta$  setae on female caudal ramus not close (equal to or greater than  $\frac{1}{3}$  length of ramus apart). Male P5 trapezoid (sides not parallel) ..... 7
- $\alpha$  and  $\beta$  setae on female caudal ramus not close (equal to or greater than  $\frac{1}{3}$  length of ramus apart). Male P5 rhomboid (sides parallel). Male P2 endopod with two terminal setae ..... *Acutiramus geddesi* (Geddes, 1968) comb. nov.
- $\alpha$  and  $\beta$  setae on female caudal ramus close together ( $\frac{1}{8}$  length of ramus apart). Male P5 trapezoid. Male P2 endopod with three terminal setae. (Plate 2A) ... *Acutiramus sesquimaculatus* (Harris, 1994) comb. nov.
- 7 Anterior bulge on female cephalosome partly obscures rostrum. Male antennule with ventral blade ..... 8
- No anterior bulge on cephalosome, rostrum prominent. No ventral blade on male antennule ..... 9
- 8 Female P5 truncated posteriorly. Female genital double-somite without lateral notch. Ventral blade on male antennule about  $\frac{1}{2}$  length of compound segment 3 + 4. (Plate 2B, p. 165) ..... *Acutiramus rufolineatus* Harris & Robertson, 1994
- Female P5 not truncated (P5 laid flat), apex with small notch. Female genital double-somite with distinct lateral notch. Ventral blade on male antennule small (less than  $\frac{1}{4}$  length of segment 3 + 4. (Plate 2E, p. 165) ..... *Acutiramus quinquelineatus* Harris & Robertson, 1994
- 9 Rostrum with clear spherical “lens”. Seta T1 on female caudal ramus very small, T3 very slender, space between T3 and T4 setae  $\frac{2}{3}$  length of oblique posterior edge of ramus. Coupling denticle on male antennule C-shaped, anterior lobe carrying  $\delta$  seta short ..... *Acutiramus bipunctatus* sp. nov.
- No spherical “lens” in rostrum. Seta T1 on female caudal ramus as large as T4, T3 same as T2, space between T3 and T4 setae  $\frac{1}{2}$  length of oblique posterior edge of ramus. Coupling denticle on male antennule not C-shaped, anterior lobe carrying  $\delta$  seta long, finger-like ..... *Acutiramus edenensis* sp. nov.

### *Acutiramus bipunctatus* sp. nov.

Figs 19–22, Plate 1C

**Type material.** HOLOTYPE adult male, length 0.56 mm, P81192; ALLOTYPE adult female length 0.64 mm, P81193; PARATYPE specimens 15 ♀♀, 10 ♂♂, P81194, deposited at AM, Sydney. Additional paratypes deposited at NHM, London. All collected from *Zonaria* sp., sublittoral, Point Vernon, Hervey Bay, Queensland (25°15'S 152°47'E), V. A. Harris, 1997.

**Diagnosis.** Conspicuous transparent oval lens-like body in rostrum of male and female; P3 endopod with internal seta on segment 1; space between T3 and T4 setae on female caudal ramus wide ( $\frac{2}{3}$  length of bevelled edge); no plumose setae on segment 2 of male antennule, no ventral blade on segment 3, segment 4 with characteristic C-shaped coupling denticle, dactylus cylindrical (almost as long as segment 3+4); female rostrum prominent, not obscured by median anterior bulge of cephalosome; “shoulders” of male cephalosome rounded, no epaulet present; female caudal ramus long (18% body length), narrow (l/w 3.7), sides straight without setules along medial edge,  $\alpha$  and  $\beta$  setae not close, terminal seta T1 to T4 plain, T1 very small, recessed; internal seta present on segment 1 of P4 endopod; female P5 exopod truncated, almost rectangular.

**Biometric data.** *Females* (N=12): maximum length ( $L_{\max}$ ) mean 0.62 mm, range 0.57–0.68 mm, body length ( $L_{\text{urs}}$ ) mean 0.59 mm, range 0.55–0.63 mm; cephalosome width (W) mean 0.43 mm, range 0.41–0.44 mm; rostrum width (R) 0.10 mm; genital double somite width 0.21 mm, length 0.16 mm; caudal ramus width 0.03 mm, length 0.11 mm.

Ratios:  $L_{\text{urs}}/W$  1.39;  $W/R$  4.43; genital double-somite w/l 1.3, arch 50% of somite length; caudal ramus 18% of  $L_{\text{urs}}$ , ramus l/w 3.7, Hicks' index for  $\beta$  51%.

*Males* (N = 11): maximum length ( $L_{\max}$ ) mean 0.56 mm, range 0.52–0.58 mm, body length ( $L_{\text{urs}}$ ) mean 0.53 mm, range 0.49–0.55 mm; cephalosome width (W) mean 0.44 mm; caudal ramus width 0.035 mm, length 0.045 mm; antennule fully extended (N = 7) 0.13 mm; spermatophore  $0.18 \times 0.07$  mm.

Ratios:  $L_{\text{urs}}/W$  1.2; caudal ramus l/w 1.2; antennule 23% of body length  $L_{\text{urs}}$ , antennule segment 2 34%, segments 3+4 35% and dactylus 24% of antennule length; spermatophore 30% of body length  $L_{\text{urs}}$ .

**Description.** *Adult females* (Fig. 19A; Plate 1C, p. 163): pale yellow or colourless with small pale red dorsal patch immediately behind dark red eyespot, dorsal region of metasome segments pale red. Outline of cephalosome a truncated semi-ellipse with slight dorsal bulge above rostrum, rostrum not obscured. Conspicuous clear oval lens-like body

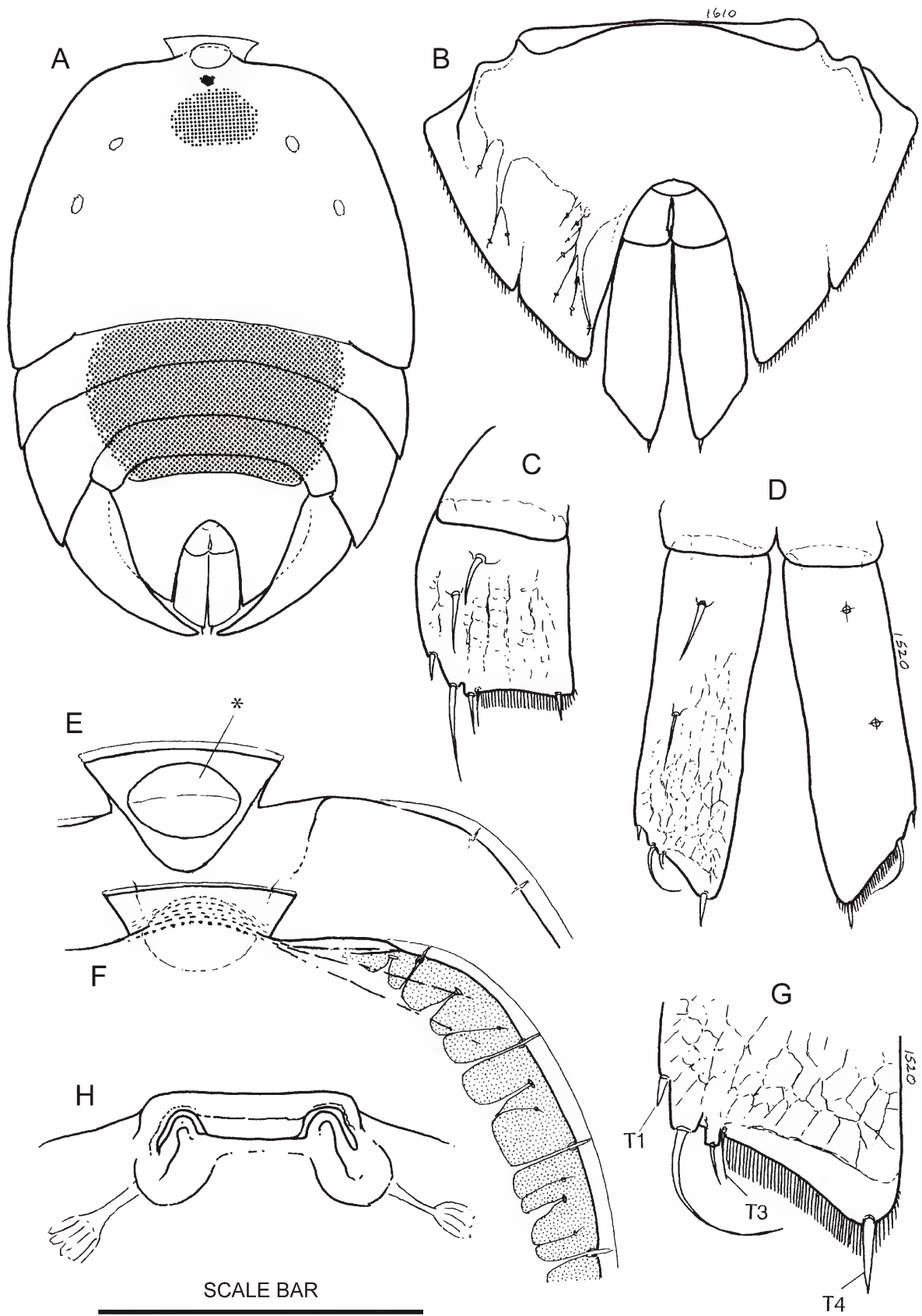


Figure 19. *Acutiramus bipunctatus* sp. nov. Female: (A) adult; (B) genital double-somite; (D) caudal rami; (E) rostrum (ventral showing "lens" \*); (F) rostrum dorsal; (G) detail of terminal setae on caudal ramus; (H) genital opening. Male: (C) caudal ramus. Scale bar: A = 0.34 mm. B, E, F = 0.15 mm. C, H = 0.08 mm. D = 0.1 mm. G = 0.04 mm.



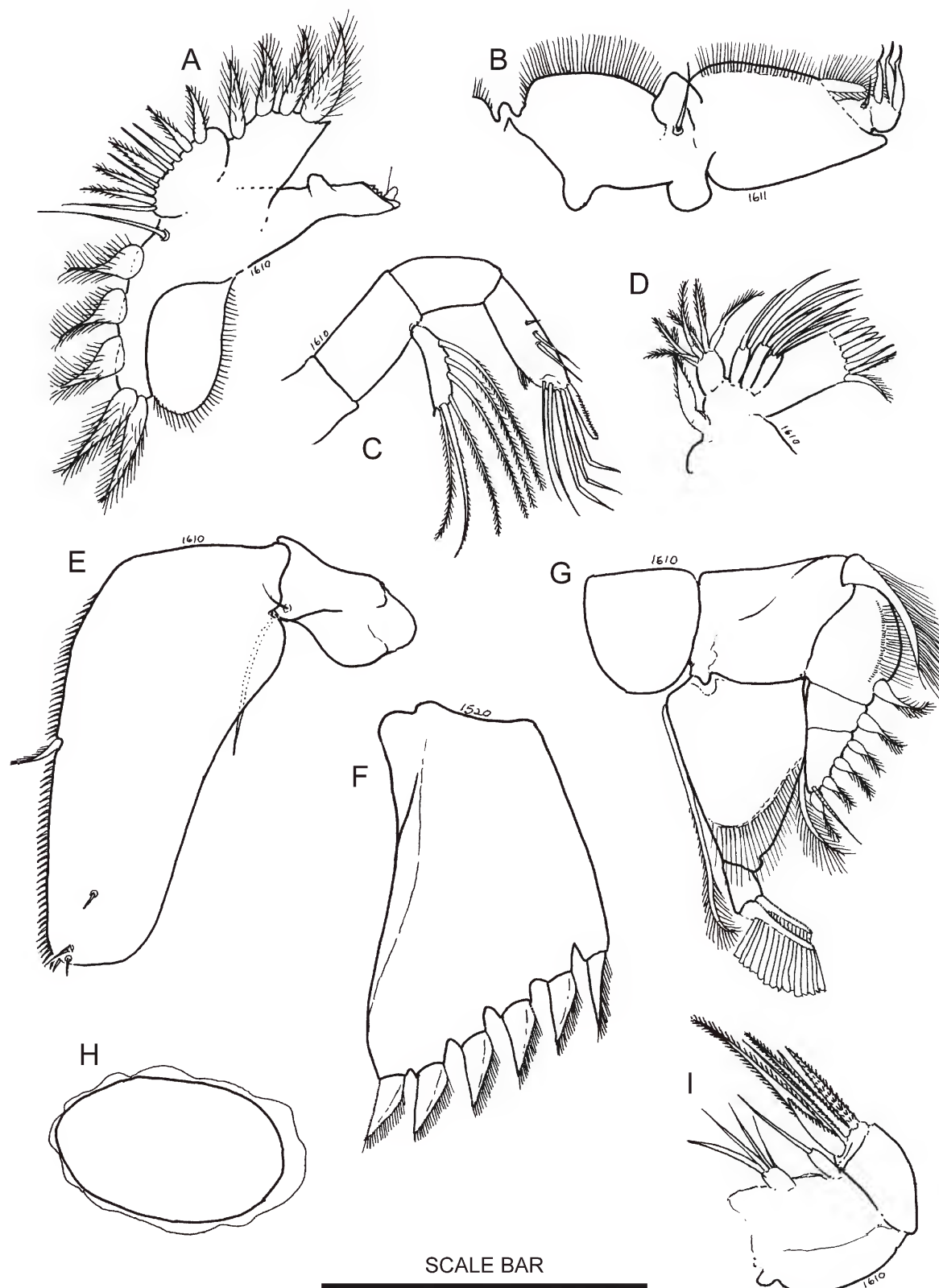


Figure 20. *Acutiramus bipunctatus* sp. nov. Female: (A) mandible; (B) maxilliped; (C) antenna; (D) maxillule; (E) P5 (dorsal); (G) P1; (H) isolated egg; (I) maxilla. Male: (F) P5 (dorsal). Scale bar: A, E = 0.15 mm B, D, F = 0.08 mm C, G = 0.13 mm I = 0.1 mm.

present in rostrum immediately in front of eyespot (Fig. 19E). Dorsal surface with small circular pits 2–3  $\mu\text{m}$  in diameter, low ridges tangential to anterior border. Hyaline border 8  $\mu\text{m}$  wide. Genital double-somite (Fig. 19B) posterior lobes narrow, pointed posteriorly, prominent anterolateral

ridge, dorsal surface pitted, edge with fine border setules, notch and short cleft separates anterior and posterior lobes, posterior arch almost half length of genital double-somite,  $\frac{2}{3}$  of caudal furca enclosed in arch. Caudal rami (Fig. 19D, G) long, narrow, rhomboid with almost parallel sides (length

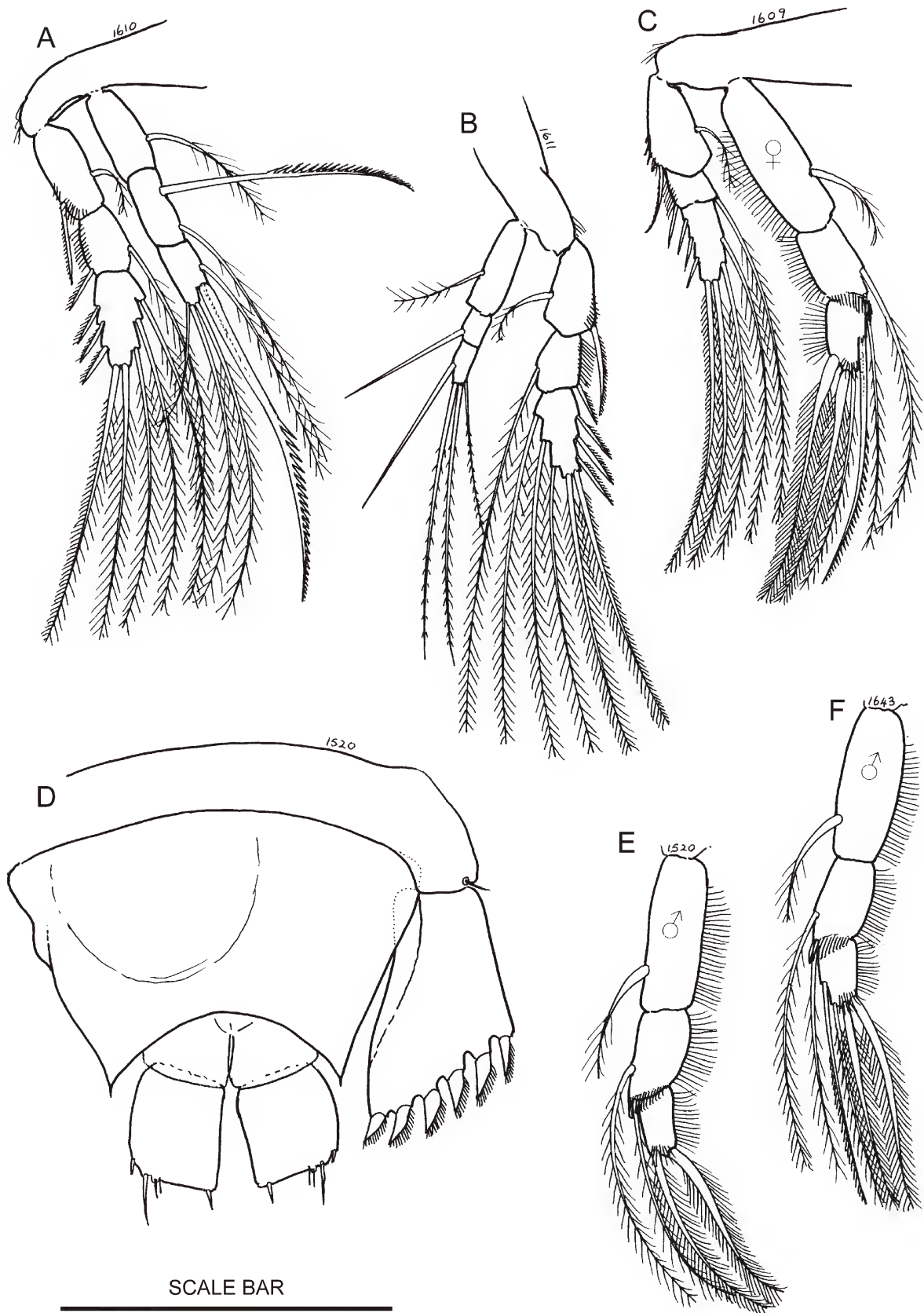


Figure 21. *Acutiramus bipunctatus* sp. nov. Female: (A) P3; (B) P4; (C) P2. Male: (D) genital double-somite and P5; (E) P2 endopod; (F) abnormal P2 endopod (see text). Scale bar: A–F = 0.13 mm.

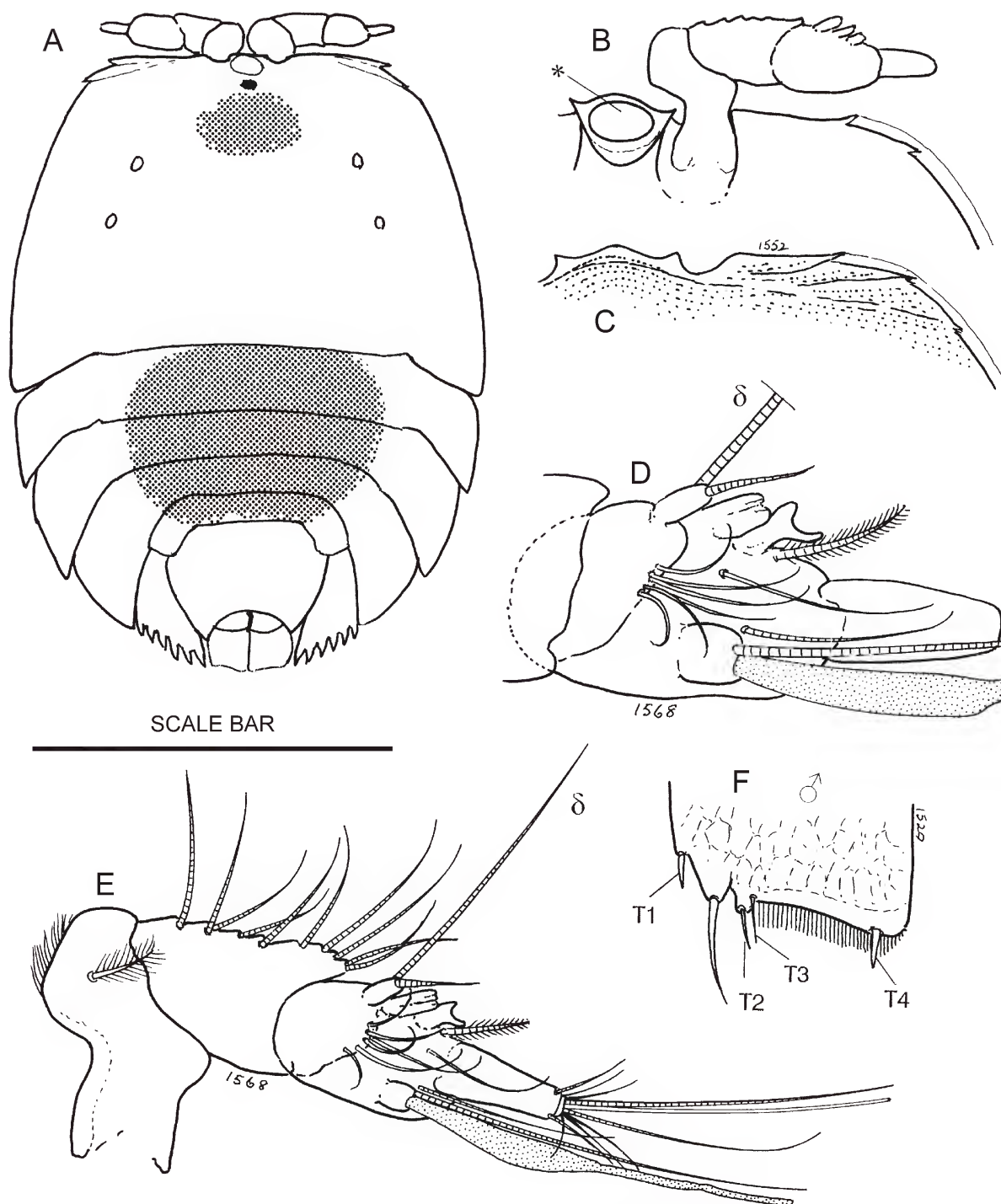


Figure 22. *Acutiramus bipunctatus* sp. nov. Male: (A) adult; (B) rostrum (ventral, \* "lens"); (C) anterior cephalosoma (dorsal); (D, E) antennule; (F) caudal ramus (detail). Scale bar: A = 0.34 mm. B, C = 0.15 mm. D, F = 0.06 mm. E = 0.08 mm.

3½ times width), medial and lateral edges without setules, dorsal surface with faint reticulation.  $\alpha$  and  $\beta$  setae not close,  $\beta$  seta half way down ramus, terminal setae plain, T1 small, recessed at lateral corner, T2 small, T3 very small and delicate, T3 lies extremely close to T2 (on many specimens T2 and T3 appear to be absent, but this is probably due to the P5 limb rubbing against the posterior border of the caudal ramus and breaking off the setae), posterior border slightly concave with fine setules. No plumulose setae on antennule. Structure and setation of mouth parts and ambulatory limbs

typical of family. Antenna exopod with five plumulose setae and one plumulose spinous seta (Fig. 20C), endopod segment 2 with three lateral setae, geniculate setae with plain terminal portion, comb-like claw ½ length of shortest geniculate seta. Mandible (Fig. 20A) without setules on anterior lobe of palp or molar process. Maxillule (Fig. 20D) with single seta on exopod. Maxilla (Fig. 20I) and maxilliped (Fig. 20B) as shown in figures. No area of denticulate setules on P1 endopod (Fig. 20G). Serrulate spinous seta on P2 endopod segment 3 shorter than endopod (0.8:1) (Fig. 21C).



Serrate spinous seta on P3 endopod segment 2 as long as endopod (Fig. 21A), large serrate spinous seta on segment 3 of endopod very long (1.5:1). Endopod of P3 and P4 with internal seta on segment 1, one plain spinous setae on P4 segment 2 and 3 (Fig. 21B). P5 exopod broad, truncated posteriorly, appears almost rectangular when laid flat, first dorsal seta small, two small apical setae, dorsal surface with pits (Fig. 20E). Females carry four or five very large eggs in brood chamber (eggs measure  $0.1 \times 0.06$  when first laid).

**Adult males** (Fig. 22A), colouration same as female. Anterior outline of cephalosome a truncated semi-ellipse with small bulge above rostrum, shoulders rounded (Fig. 22C). Rostrum with conspicuous oval lens-like body just in front of eyespot seen from ventral view (Fig. 22B). Dorsal pits and hyaline border same as female. Caudal ramus (Fig. 19C) slightly longer than broad (1.15:1), lateral edge convex, posterior border between T2 and T4 slightly concave with border of fine setules, T4 set in from medial corner, T2 small, T3 very small, thin and very close to T2 (Fig. 22F). Antennule (Fig. 22E) with plumose seta on segment 1, no plumose setae on segment 2, no ventral process or blade, distal coupling denticle with C-shaped edge accompanied by a pinnate seta (Fig. 22D), dactylus elongate, cylindrical. Male P2 endopod (Fig. 21E) with two or four plumose setae (Fig. 21F, see Remarks below). Male P5 exopod trapezoid, no setules at base of terminal setae (Fig. 20F).

**Etymology.** The species name refers to the smaller red dot on the cephalosome and a larger red area on the metasome segments.

**Remarks.** The exopods of female P5 limbs wrap round and touch the bevelled edge of the caudal rami, consequently the delicate T2 and T3 setae are frequently broken off and not always seen. This gives the impression that T3 is missing in this species. Critical examination of recently metamorphosed females confirm that both T2 and T3 are present in this species.

During measurement of the eleven male animals it was noticed that seven specimens had two plumose terminal setae to segment 3 of P2 endopod, but four animals had four terminal setae (one serrulate spinous seta plus three plumose setae). Because four terminal setae is the normal condition for all female animals in the Porcellidiidae, this unusual observation probably indicates a case of paedomorphosis. The presence of four terminal setae on male P2 has only been recorded for two other species, *Dilatatiocauda tristanensis* (Wiborg, 1964) and *D. plana* (Tiemann, 1977), see Harris (2002).

**Distribution.** *Acutiramus bipunctatus* is abundant on *Halimeda* sp., *Zonaria* sp., and *Eucheuma* sp., at Point Vernon, Hervey Bay, Queensland, but it is also found in small numbers on *Caulerpa* sp., *Lethesia* and *Martensia* spp., in the same locality. The type series, PV6.7/97, contains 78 ♀♀ (70 with eggs), 41 ♂♂, 5 juveniles. Sample PV7. 8/97 from *Eucheuma denticulata* contains 407 ♀♀, 119 ♂♂ + 6 ♂♂ coupled with juvenile, V. A. Harris, 1997.

## *Acutiramus edenensis* sp. nov.

Figs 23–25

**Type material.** HOLOTYPE adult male, length 0.48 mm, P81201; ALLOTYPE adult female, length 0.68 mm, P81202; PARATYPE material, 5 ♀♀, 3 ♂♂, 1 ♂ coupled to juvenile + 2 juveniles, P81203, deposited at AM, Sydney. Additional paratypes deposited at NHM, London. All collected from *Ecklonia radiata* at Arrawarra Headland, Woolgoolga, northern NSW (30°03'S 153°02'E), V. A. Harris, 1982.

**Diagnosis.** No plumose setae on segment 2 of male antennule, anterior lobe with  $\delta$  on segment 3 long, finger-like, ventral blade absent, coupling denticles on segment 4 with serrated edge (Fig. 25G), dactylus broad with terminal claw-like hook and large lateral indentation (Fig. 25B, C); P3 endopod with internal seta on segment 1; rostrum prominent, without “lens”, no median anterior bulge to cephalosome; male shoulders rounded, no epaulette; lateral edge of female caudal ramus slightly convex, posterior half of medial edge with setules, terminal setae plain, T1 as large as T4, T2 and T3 close together, not parallel to posterior edge, space between T3 and T4 about  $\frac{1}{3}$  length of oblique posterior edge,  $\alpha$  and  $\beta$  not close ( $\frac{1}{2}$  length of ramus apart); female P5 exopod truncated lanceolate; male spermatophore very small ( $< 15\%$  of body length).

**Biometric data.** *Females* (N = 20): maximum length ( $L_{\max}$ ) mean 0.67 mm, range 0.63–0.72 mm, body length ( $L_{\text{urs}}$ ) mean 0.64 mm, range 0.59–0.69 mm; cephalosome 0.42 mm, range 0.40–0.44 mm; rostrum width 0.115 mm; genital double-somite width 0.23 mm, length 0.16 mm, height of arch 0.09 mm; caudal ramus length 0.78 mm, width 0.28 mm.

Ratios:  $L_{\text{urs}}/W$  1.52;  $W/R$  3.5; genital double-somite w/l 1.47, arch 56% of somite length; caudal ramus 12% of body length ( $L_{\text{urs}}$ ), caudal ramus l/w 2.8, Hicks index for  $\beta$  53%.

*Males* (N = 15): maximum length ( $L_{\max}$ ) mean 0.49 mm, range 0.45–0.51 mm, body length ( $L_{\text{urs}}$ ) mean 0.47 mm, range 0.44–0.49 mm; cephalosome width 0.35 mm; caudal ramus length 0.02 mm, width 0.018 mm; antennule fully extended 0.15 mm; spermatophore 0.06 mm  $\times$  0.018 mm.

Ratios:  $L_{\text{urs}}/W$  1.35; caudal ramus l/w 1.1; antennule 32% of body length ( $L_{\text{urs}}$ ), antennule segment 2 23%, segment 3+4 40%, dactylus 33% of antennule length; spermatophore 12% of body length ( $L_{\text{urs}}$ ).

**Description.** *Adult females* (Fig. 23A): colourless, anterior outline of cephalosome semicircular, rostrum prominent, no median bulge above rostrum, no lens-like structure in rostrum. Dorsal pits small 2–3  $\mu\text{m}$ , hyaline border granulated, 8–10  $\mu\text{m}$  wide (Fig. 25E). Very few dorsal sensilla. Genital double-somite (Fig. 23F) almost semicircular in outline without anterolateral ridge, notch and short cleft mark boundary between anterior and posterior lobes, posterior lobe about 30% of lateral edge, arch of genital double-somite deep, accommodates more than  $\frac{3}{4}$  of caudal furca. Genital opening as shown in Fig. 23E. Caudal ramus (Fig. 23B) rhomboid, length about  $2\frac{1}{2}$  times width, medial edge straight with fine setules from level of  $\beta$  to T4, lateral edge slightly convex with border setules distally,  $\alpha$  and  $\beta$  setae not close, terminal setae plain, T2 and T3 very close together, space between T3 and T4 with fine setules,  $\frac{1}{2}$  length of oblique posterior edge, T4 inserted at rounded posterior apex. No plumose setae on antennule. Structure

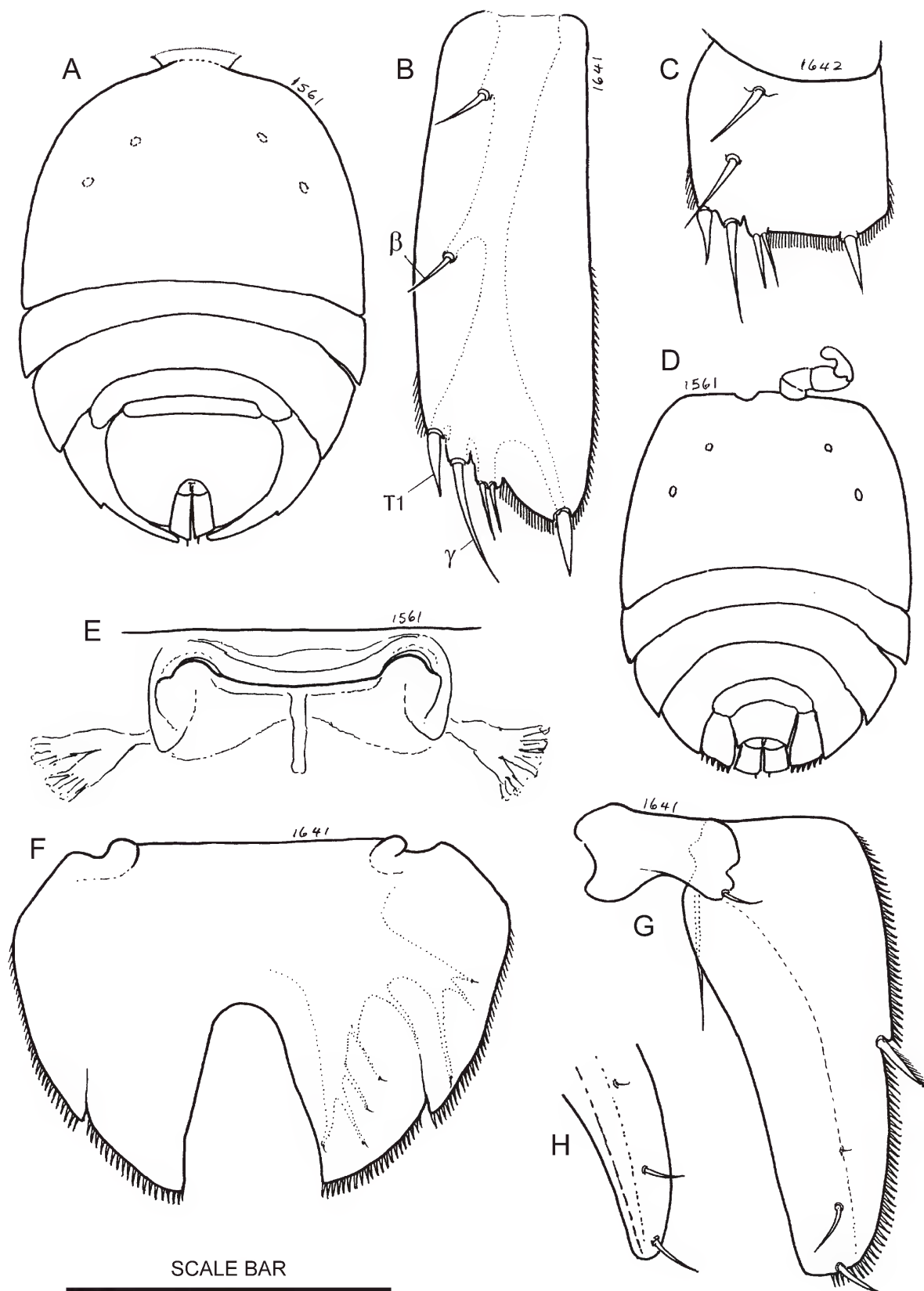


Figure 23. *Acutiramus edenensis*, sp. nov. Female: (A) adult; (B) caudal ramus; (E) genital opening; (F) genital double-somite; (G, H) P5 (dorsal). Male: (C) caudal ramus; (D) adult. Scale bar: A, D = 0.45 mm. B, C = 0.06 mm. E = 0.08 mm. F, G = 0.15 mm.

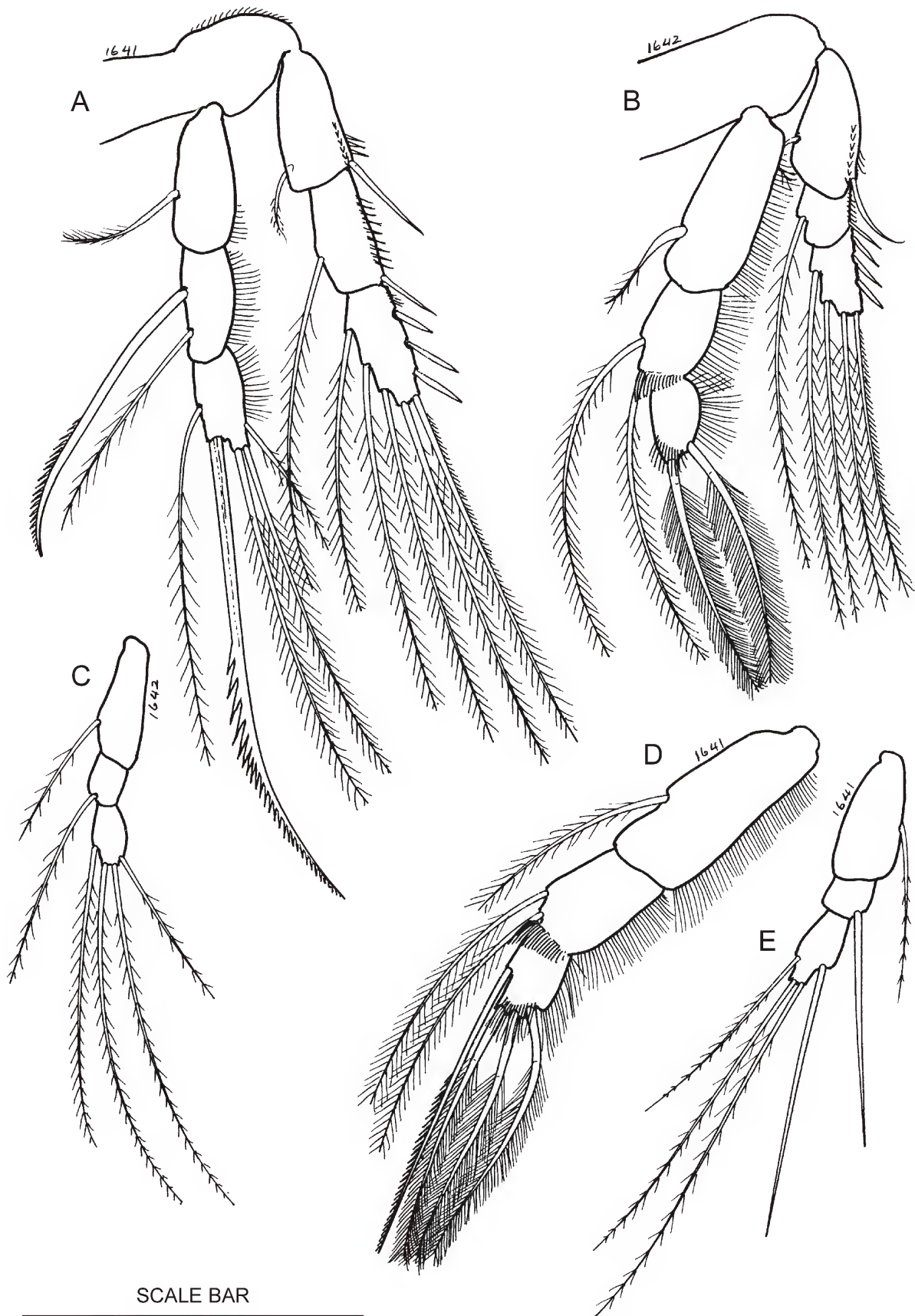


Figure 24. *Acutiramus edenensis* sp. nov. Female: (A) P3; (D) P2 endopod; (E) P4 endopod. Male: (B) P2; (C) P4 endopod. Scale bar: A–E = 0.1 mm.



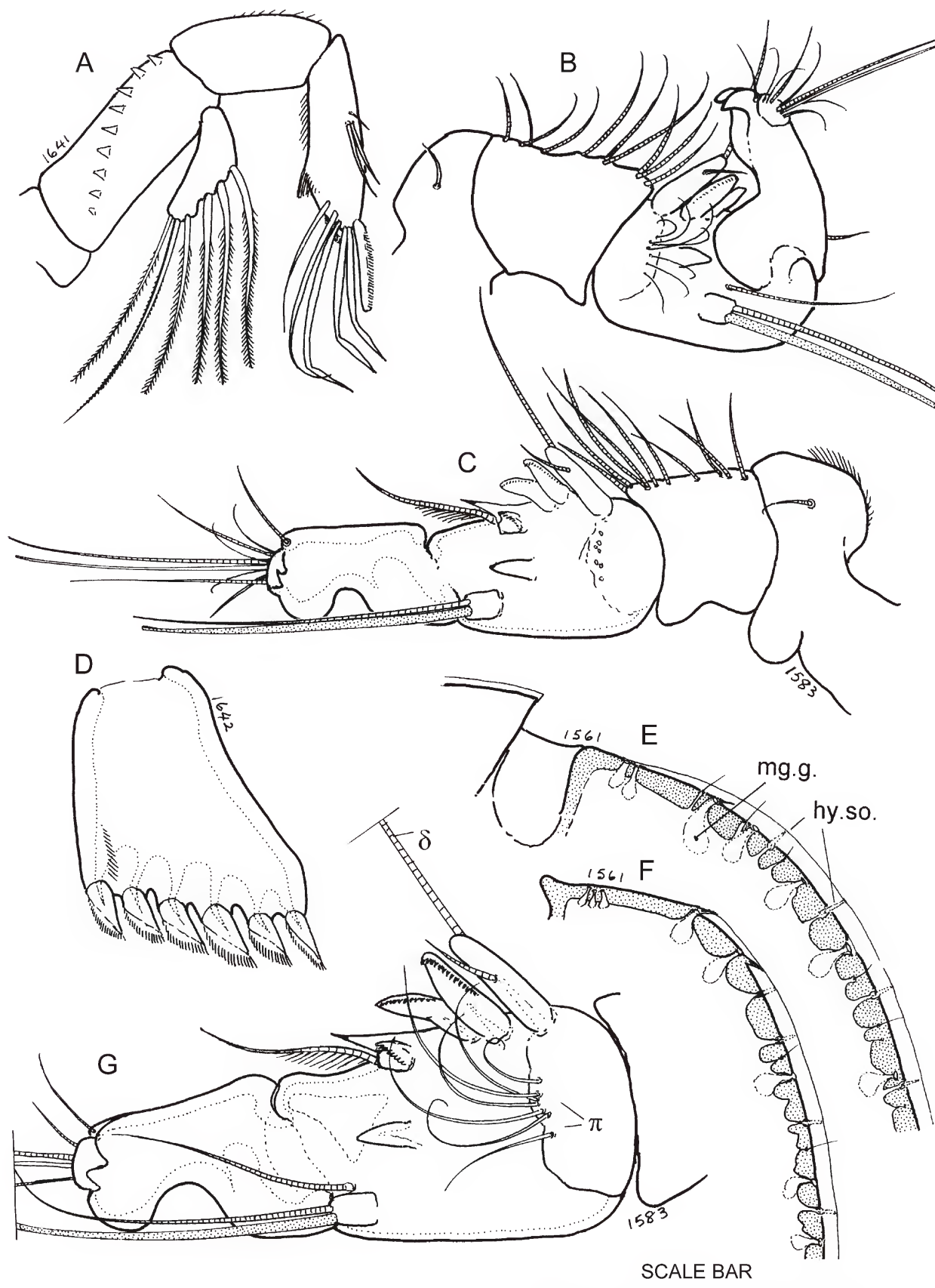


Figure 25. *Acutiramis edenensis* sp. nov. Female: (A) antenna; (E) border of cephalosome. Male: (B, C, G) antennule ( $\pi$  setae not shown in C); (D) P5 (ventral); (F) border of cephalosome. Scale bar: A, C, D = 0.08 mm. B = 0.13 mm. E, F = 0.15 mm. G = 0.06 mm.

**Table 1.** Difference in body size and number of eggs carried by the female in *A. edenensis* collected from northern New South Wales, Australia (latitude 30°S) and cooler temperate waters of southern NSW (latitude 37°S).

	Latitude 30°S N = 20	Latitude 37°S N = 26
L <sub>urs</sub> mean	0.64 mm, range 0.59–0.69 mm	0.75 mm, range 0.72–0.81 mm
W mean	0.42 mm, range 0.40–0.45 mm	0.50 mm, range 0.45–0.53 mm
R mean	0.115 mm	0.135 mm
	Ratios	
L <sub>urs</sub> /W	1.5	1.53
W/R	3.7	3.65
Number of eggs	mean 5, range 4–6	mean 8, range 6–12

and setation of mouth parts and ambulatory limbs typical of family. Antenna (Fig. 25A) with row of triangular setules on basis, five plumulose setae plus one finely serrulate spinous seta on exopod, segment 2 of endopod with three lateral setae, end part of geniculate setae plain, terminal claw comb-like, long. Mandibular palp without setules on anterior lobe. Maxillule, maxilla and maxilliped as described for *A. bipunctatus*. No peg area on P1 endopod. Serrulate spinous seta on segment 3 of P2 endopod shorter than endopod (0.75:1) (Fig. 24D). P3 with internal seta on segment 1 of endopod, serrulate spinous seta on segment 2 of P3 endopod (Fig. 24A) shorter than endopod, large serrate spinous seta on segment 3 longer than endopod (1.37:1). Endopod of P4 with internal seta on first segment, plain spinous seta on segment 2 and first (internal) seta of segment 3 (Fig. 24E). Exopod of P5 lanceolate, truncated posteriorly, two dorsal setae, one very small and one larger sub-terminal, one apical seta, dorsal surface with pits (Figs 23G, H). See Remarks for number of eggs carried by the female.

**Adult males** (Fig. 23D) colourless. Anterior of cephalosome truncated semi-ellipse, no medial bulge above rostrum or lens-like body in rostrum, shoulders rounded. Caudal ramus (Fig. 23C) quadrate, medial edge straight, lateral edge slightly convex, T2 and T3 very close, T4 set in from medial corner, terminal fringe of fine setules. Antennule (Figs 25C), no plumose setae on segment 2, anterior lobe on segment 3 extended as long finger-like process bearing  $\delta$  and  $\delta'$  setae, no ventral process or blade on segment 3, two elongate coupling denticles with comb-like edge on segment 4 project forward parallel to anterior lobe, distal denticle small with pinnate seta, small pointed structure in “palm” of segment 4 (Fig. 25G), dactylus almost as long as segment 3+4 with characteristic deep indentation on its posterior edge, hooked terminally (Figs 25B, G). Endopod of P2 with two plumose setae on terminal segment (Fig. 24B). All setae on P4 endopod plumose, not spinous (Fig. 24C). P5 trapezoid, no setules at base of terminal setae except first or lateral seta (Fig. 25D). Spermatophore extremely small (about 12% of body length).

**Etymology.** The specific name refers to Eden NSW where the species was first discovered.

**Remarks.** A difference in body size and number of eggs carried by the female has been noticed between animals collected from northern NSW and those found in cooler temperate waters of southern NSW (Table 1).

**Distribution.** *Acutiramus edenensis* has a wide geographical range covering more than 7° of latitude. The type series was collected from mixed seaweeds (including *Ecklonia radiata*)

in the infralittoral fringe, Woolgoolga (30°03'S), Wo3. 11/82, 35 ♀♀ (19 ovigerous), 17 ♂♂ plus 4 ♂♂ coupled to juveniles, 13 juveniles. It has been found at Broulee, NSW, (35°52'S) on *Caulerpa* sp., and in washings from *Ecklonia radiata* holdfasts at Twofold Bay, Eden, NSW, (37°06'S), TB4. 12/82, 11 ♀♀, 3 ♂♂, V. A. Harris 1982.

### *Acutiramus iwasakii* sp. nov.

Figs 26, 28, 29

**Type material.** HOLOTYPE adult male, length 0.54 mm, mounted on slide [1360], P88555; ALLOTYPE adult female without egg mass, length 0.70 mm, mounted on slide [939], P88556 deposited at AM, Sydney; additional PARATYPES deposited at NHM, London. All collected from inside *Turbo torquatus* shells inhabited by hermit crabs of the species *Pagurus sinuatus*, O'Hara Head, Kioloa, NSW (25°34'S 150°25'E, estimated), V. A. Harris, 1976.

**Diagnosis.** Female rostrum unique, anterior edge with three curves giving an undulating appearance (Fig. 26D), hyaline border present; male rostrum with anterior point, not obscured by cephalosome above; setae on male antennule sensory lobe and dactylus extremely long (> than length of antennule); female caudal ramus rhomboid with pinnate T4 at posterior apex, setules down length of medial edge, gap between  $\gamma$  and T2 equals gap between T3 and T4,  $\alpha$  and  $\beta$  setae close ( $\frac{1}{2}$  of ramus length apart); seta T1 on male caudal ramus very small; female genital double-somite with short cleft between anterior and posterior lobes; P3 endopod without seta on segment 1 (0:2:1, 3, 1); P4 endopod without seta on segment 1 (0:1:1, 2, 1).

**Biometric data.** *Females* (N = 6): maximum length (L<sub>max</sub>) mean 0.72 mm, length to posterior of genital double-somite (L<sub>urs</sub>) mean 0.66 mm; width of cephalosome (W) 0.50 mm; rostrum width (R) 0.10 mm; genital double-somite length 0.13 mm, width 0.22 mm, arch 0.09 mm; caudal ramus length 0.08 mm, width 0.04 mm.

Ratios: L<sub>max</sub>/W 1.45, L<sub>urs</sub>/W 1.35; cephalosome W/R 5.0; genital double-somite width 44% of cephalosome width, w/l 1.7, arch/l 0.7; caudal ramus l/w 2.0, ramus as % of L<sub>max</sub> 13%, Hicks' index for  $\alpha$  83%,  $\beta$  67%,  $\alpha$ - $\beta$  17%.

*Males* (N = 4): maximum length 0.54 mm; cephalosome width 0.40 mm; antennule 0.126 mm; angle of P5 apex 45°.

Ratios: Caudal ramus l/w 0.78, Hicks' index for  $\alpha$  60%,  $\beta$  50%,  $\alpha$ - $\beta$  11%; antennule 23% of L<sub>max</sub>, segment 3+4 43%, dactylus 16% of antennule length.

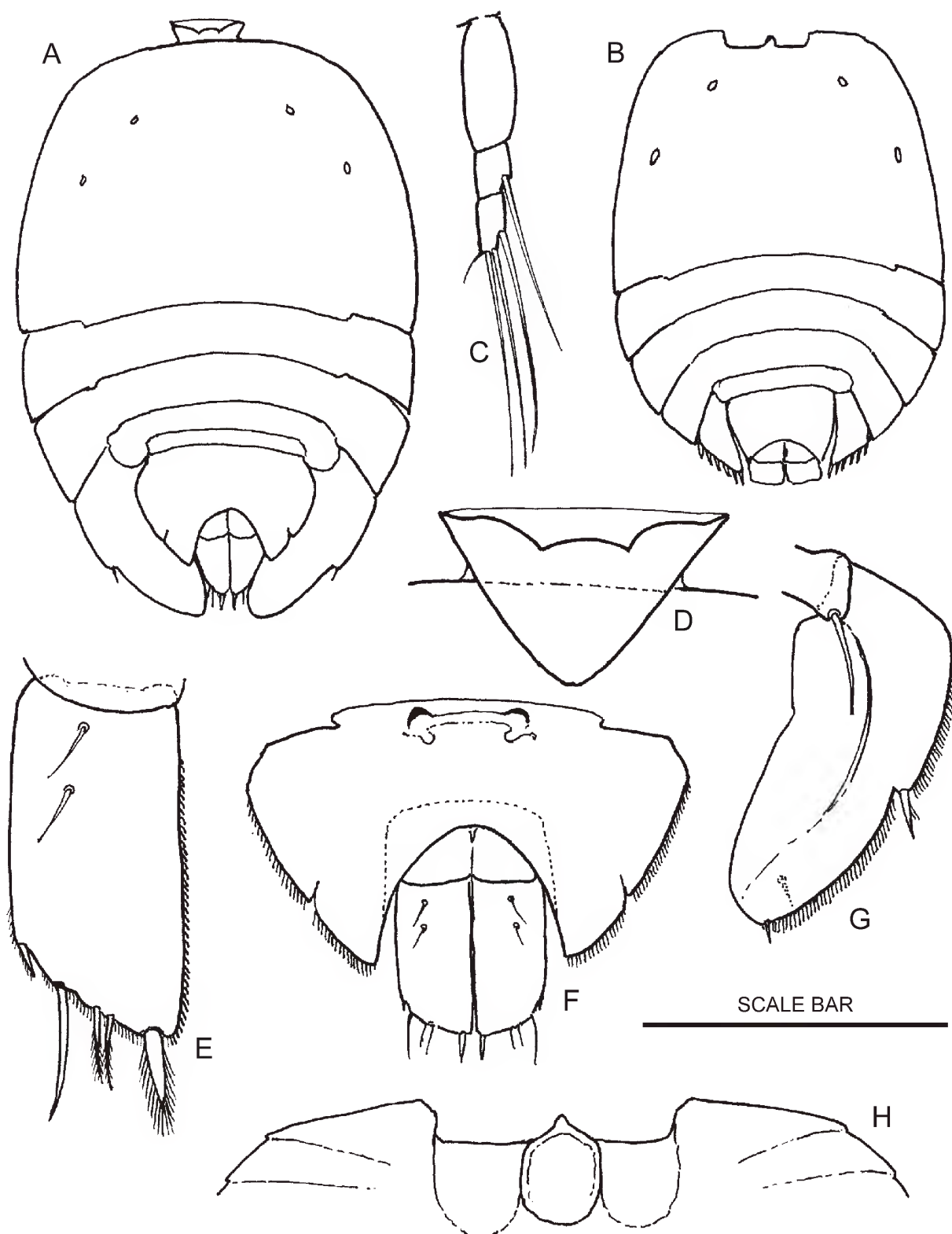


Figure 26. *Acutiramus iwasaki* sp. nov. Female: (A) adult; (C) P4 endopod; (D) rostrum (ventral); (E) left caudal ramus; (F) genital double-somite; (G) P5 ventral. Male: (B) adult; (H) anterior cephalosoma (ventral showing rostrum). Scale bar: A, B = 0.36 mm. D = 0.12 mm. E = 0.07 mm. F, G, H = 0.16 mm.

**Description.** *Adult females* (Fig. 26A): colourless, transparent. Anterior of cephalosoma semicircular, no bulge above rostrum. Rostrum prominent, with characteristic undulating anterior border (Fig. 26D). Dorsal pits small (3–4

µm), hyaline border 8 µm, dorsal surface without hair-like sensilla. Genital double-somite narrow, pointed posteriorly with a distinct cleft separating anterior and posterior lobes, border setules present, arch encloses about ½ of caudal ramus



(Fig. 26F). Caudal ramus (Fig. 26E) rhomboid with pinnate T4 at apex, medial edge with setules,  $\alpha$  and  $\beta$  setae not very close, T1 very small at lateral end of bevelled posterior edge, T2 and T3 close, equally spaced between  $\gamma$  and T4, setules along bevelled edge. No setules on labrum. Structure and setation of mouthparts and ambulatory limbs are typical of family. Geniculate setae on segment 2 of antenna endopod with plain terminal segment, terminal claw not comb-like, as long as first geniculate seta (Fig. 29A). Maxillule (Fig. 29C), P3 does not have internal seta on segment 1 of endopod (0:2:1,3,1). The serrate spinous terminal seta on P3 endopod is slender and not much longer than the endopod (1.2:1). No internal seta on segment 1 of P4 (0:1:1,2,1), (Fig. 26C). P5 is broad and partly covers the genital double-somite, it is rounded posteriorly with an apical seta and one sub-terminal dorsal seta (Fig. 26G). Mature females carry four or five large eggs.

**Adult males** (Fig. 26B) colourless. Anterior of cephalosome only slightly truncated, shoulders rounded bearing two rows of dorsal pits arranged along a ridge (Fig. 29D). The rostrum has a prominent anterior point that is not obscured dorsally. The rostrum and antennule sockets are recessed in a medial anterior concavity of the cephalosome (Fig. 26H). Dorsal pits and hyaline border as for female. Caudal ramus sub-quadrate ( $l/w = 0.8$ ),  $\alpha$  and  $\beta$  setae close together ( $1/10$  of ramus length), terminal setae appear to be plain, T1 is very short, recessed, T2 and T3 close, gap between T3 and T4 is  $1/3$ – $1/2$  width of ramus (Fig. 28B). Antennule is unique for the length of its setae (Fig. 28G). Both the terminal seta on dactylus and  $\sigma$  seta on sensory lobe are as long, or longer, than length of extended antennule,  $\delta$  seta  $2/3$  length of antennule, annulate seta associated with the distal denticle is equal to segment 3+4 in length. No denticle on segment 3, two denticles on segment 4 (Fig. 28F). Structure and setation of mouthparts and ambulatory limbs as for female, but P2 has two terminal setae on segment 3 of the endopod, P5 acute trapezoid (Fig. 28D), no rows of setules at base of each terminal seta.

**Etymology.** The species has been named after Dr Nozomu Iwasaki in recognition of his studies on *Dactylopusoides* species that burrow into brown algae.

**Remarks.** Nearly all animals in the present study are heavily burdened with protozoan organisms (large thecate and small naked suctorians as well as other thecate protozoa) which obscure detail of important organs such as the caudal rami and male antennules (see Fig. 27A). For this reason it was necessary to base identification and description on three newly metamorphosed specimens that had not been colonized by protozoa.

Animals were found living inside the shells occupied by the hermit crab *Pagurus simuatus*, but not on empty shells or those occupied by the mollusc, thus the relationship appears to be commensal.

### *Acutiramus cumulus* sp. nov.

Figs 27–29

**Type material.** HOLOTYPE adult male, length 0.55 mm, dissected, P89051, and ALLOTYPE, adult female not carrying eggs, length 0.78 mm, both mounted on a slide [1651], P89052, deposited at AM, Sydney. Additional PARATYPES deposited at NHM, London. All collected from inside *Turbo torquatus* shells inhabited by hermit crabs of the species *Pagurus simuatus*, O'Hara Head, Kioloa, NSW, (25°34'S 150°25'E, estimated), V. A. Harris, 1976.

**Diagnosis.** Male rostrum without anterior point, anterior border of cephalosome convex in midline obscuring rostrum, slightly concave on each side with angular shoulders; T1 on male caudal ramus large, pinnate,  $\alpha$  and  $\beta$  setae not close together ( $1/4$  length of ramus apart); anterior border of female rostrum straight, cephalosome bulged above rostrum; female caudal ramus rhomboid with conspicuous network of ridges; terminal setae T2, T3 and T4 pinnate, equal in size and bunched up together at posterior apex; no internal seta on segment 1 of P3 endopod (0:2:1,3,1); P4 has plain internal seta on segment 1 of endopod (1:1:1,2,1); setae on male antennule not longer than antennule ( $< 1/2$  antennule length).

**Biometric data.** *Females* ( $N = 8$ ): maximum length ( $L_{\max}$ ) mean 0.78 mm, length to posterior of genital double-somite ( $L_{\text{urs}}$ ) mean 0.72 mm; width of cephalosome ( $W$ ) 0.51 mm; rostrum width ( $R$ ) 0.12 mm; genital double-somite length 0.16 mm, width 0.26 mm, arch 0.09 mm; caudal ramus length 0.10 mm, width 0.03 mm.

Ratios:  $L_{\max}/W$  1.5,  $L_{\text{urs}}/W$  1.4; cephalosome  $W/R$  4.2; genital double-somite width 50% of cephalosome width,  $w/l$  1.65, arch/ $l$  0.55; caudal ramus  $l/w$  3.1, ramus as % of  $L_{\text{urs}}$  14%, Hicks' ratios  $\alpha$  88%,  $\beta$  61%,  $\alpha$ – $\beta$  27%.

*Males* ( $N = 2$ ): maximum length 0.58 mm; cephalosome width 0.42 mm.

Ratios: Caudal ramus  $l/w$  1.0, Hicks' index for  $\alpha = 70\%$ ,  $\beta$  42%,  $\alpha$ – $\beta$  28%.

**Description.** *Adult females* (Fig. 27A): colourless, anterior of cephalosome semicircular with a distinct bulge above the rostrum. Rostrum prominent with slightly convex anterior border (Fig. 27G). Dorsal surface without hair-like sensilla, dorsal pits large (6–9  $\mu\text{m}$ ) conspicuous over all parts of the body except the caudal rami. Genital double-somite posterior lobe pointed, separated from anterior lobe by a distinct cleft (Fig. 27B). Caudal ramus (Fig. 27F) rhomboid, long (length  $2\frac{1}{2}$  times width) with conspicuous dorsal network of ridges,  $\alpha$  and  $\beta$  setae not close ( $> 1/4$  length of ramus). The arrangement of terminal setae is unique, T2, T3 and T4 are clustered together at the posterior apex of the ramus (Fig. 27F), T1 is small at the lateral end of the bevelled posterior edge and there is a gap between  $\gamma$  and T2. A terminal fringe of setules could not be seen on specimens available. Labrum without setules. Structure and setation of mouthparts and ambulatory limbs typical of family except for P3 which lacks internal seta on segment 1 of endopod. Serrated spinous seta on segment 3 of P3 much longer than endopod (1.6:1). P4 endopod (Fig. 27C) has plain internal seta on segment 1, P5 broad, rounded posteriorly with apical seta and one sub-terminal seta (Fig. 27D). Mature females carry four or five large eggs.

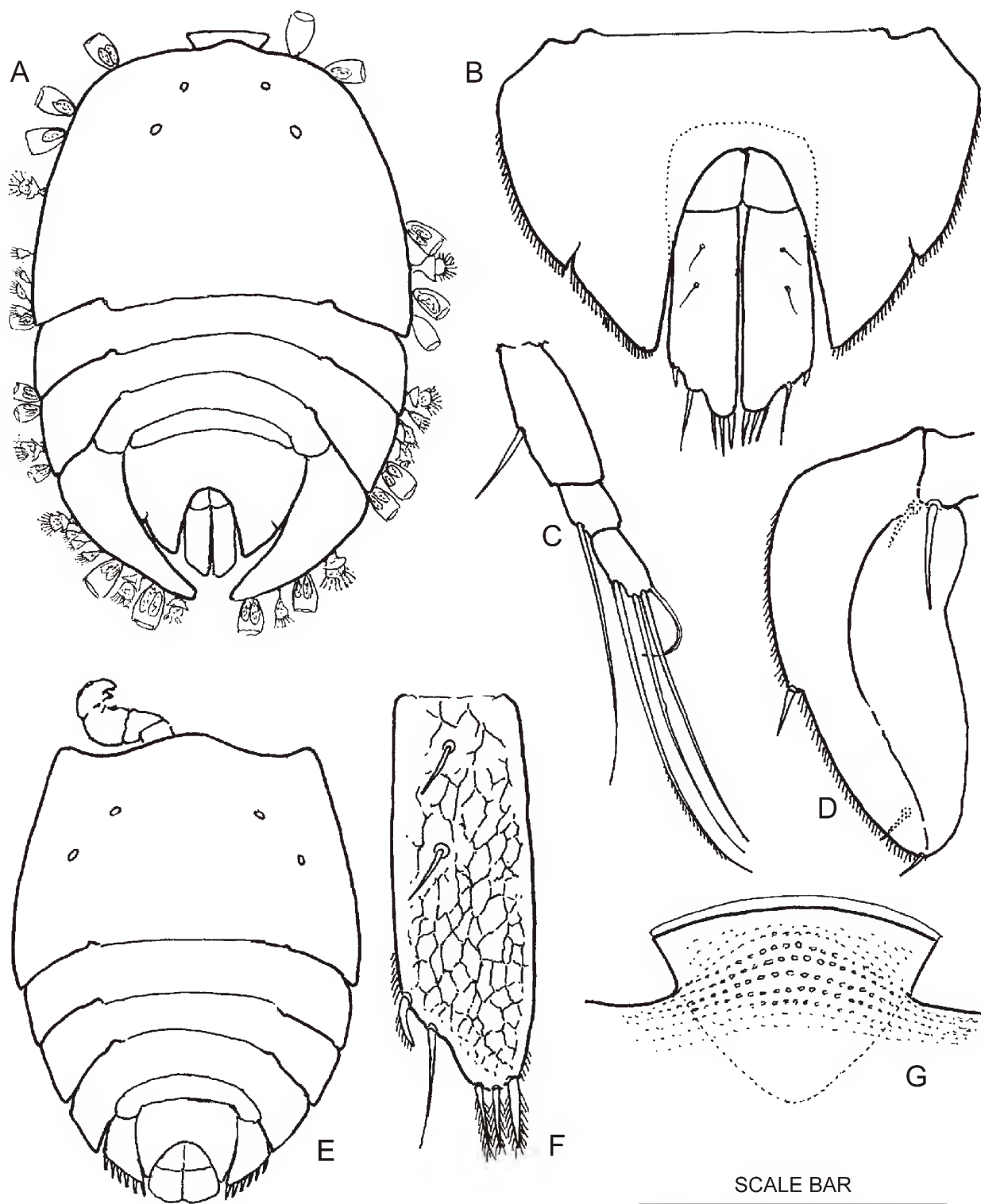


Figure 27. *Acutiramus cumulus* sp. nov. Female: (A) adult (with attached protozoa); (B) genital double-somite; (C) P4 endopod; (D) P5 (ventral); (F) left caudal ramus; (G) rostrum. Male: (E) adult. Scale bar: A = 0.42 mm. B, D = 0.16 mm. E = 0.38 mm. F = 0.07 mm. G = 0.13 mm.

**Adult males** (Fig. 27E) colourless. Anterior of cephalosome truncated, convex in midline above the rostrum and slightly concave on either side with pointed shoulders. Rostrum not pointed, obscured from above by cephalosome (Fig. 28A). Dorsal pits as for female. Caudal ramus (Fig. 28E) quadrate, lateral edge convex, dorsal surface with

rows of conspicuous pits,  $\alpha$  and  $\beta$  setae not close ( $\frac{1}{4}$  length of ramus apart). Terminal seta T1 pinnate, recessed at lateral corner, T2 and T3 pinnate close together in middle of posterior border, T4 small set in from rounded medial corner. Antennule (Fig. 29B) sensory lobe on segment 4 does not have a blade-like (acuminate) process, all setae less than

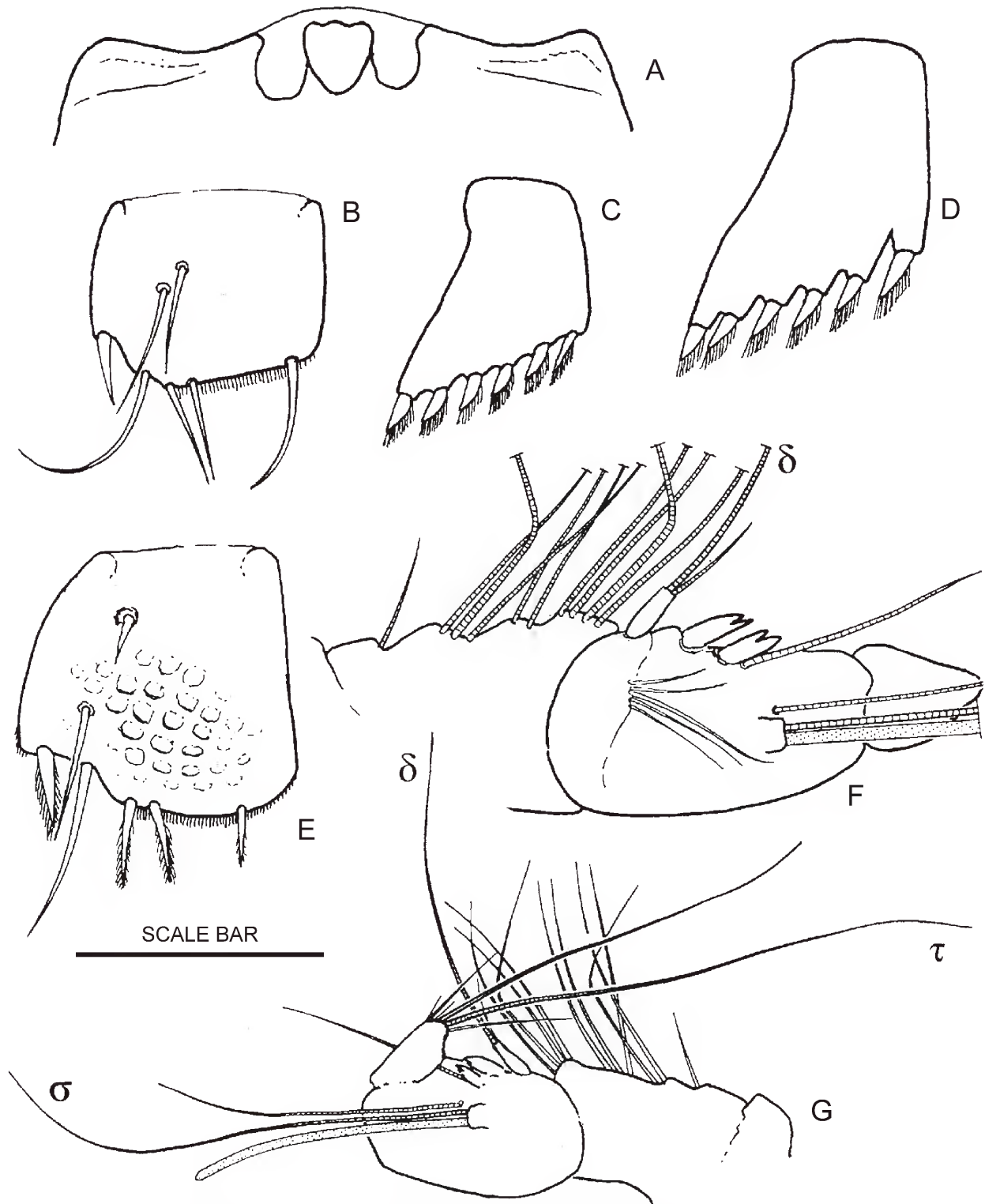


Figure 28. *Acutiramus cumulus* sp. nov. male: (A) anterior cephalosome (ventral, showing rostrum); (C) P5; (E) left caudal ramus. *Acutiramus iwasakii* sp. nov. male: (B) left caudal ramus; (D) P5; (F) antennule denticles; (G) antennule setae ( $\pi$  series not shown). Scale bar: A = 0.2 mm. B = 0.04 mm. C, D, G = 0.065 mm. E, F = 0.04 mm.

length of antennule. (No fully extended antennule available for measurement and study of denticles). Structure and setation of mouthparts and ambulatory limbs as for female. P2 has two terminal setae on segment 3 of the endopod, P5 is trapezoidal with apical angle  $47^\circ$  (Fig. 28C) no rows of setules at base of terminal setae.

**Remarks.** The trivial name refers to the way in which terminal setae T2, T3 and T4 on the female caudal ramus are heaped together at the apex (*L. cumulus* = a heap or pile), this feature has not been found on any other member of the family.

Specimens of *A. cumulus* and *A. iwasakii* were found living together in the same shells inhabited by hermit crabs.



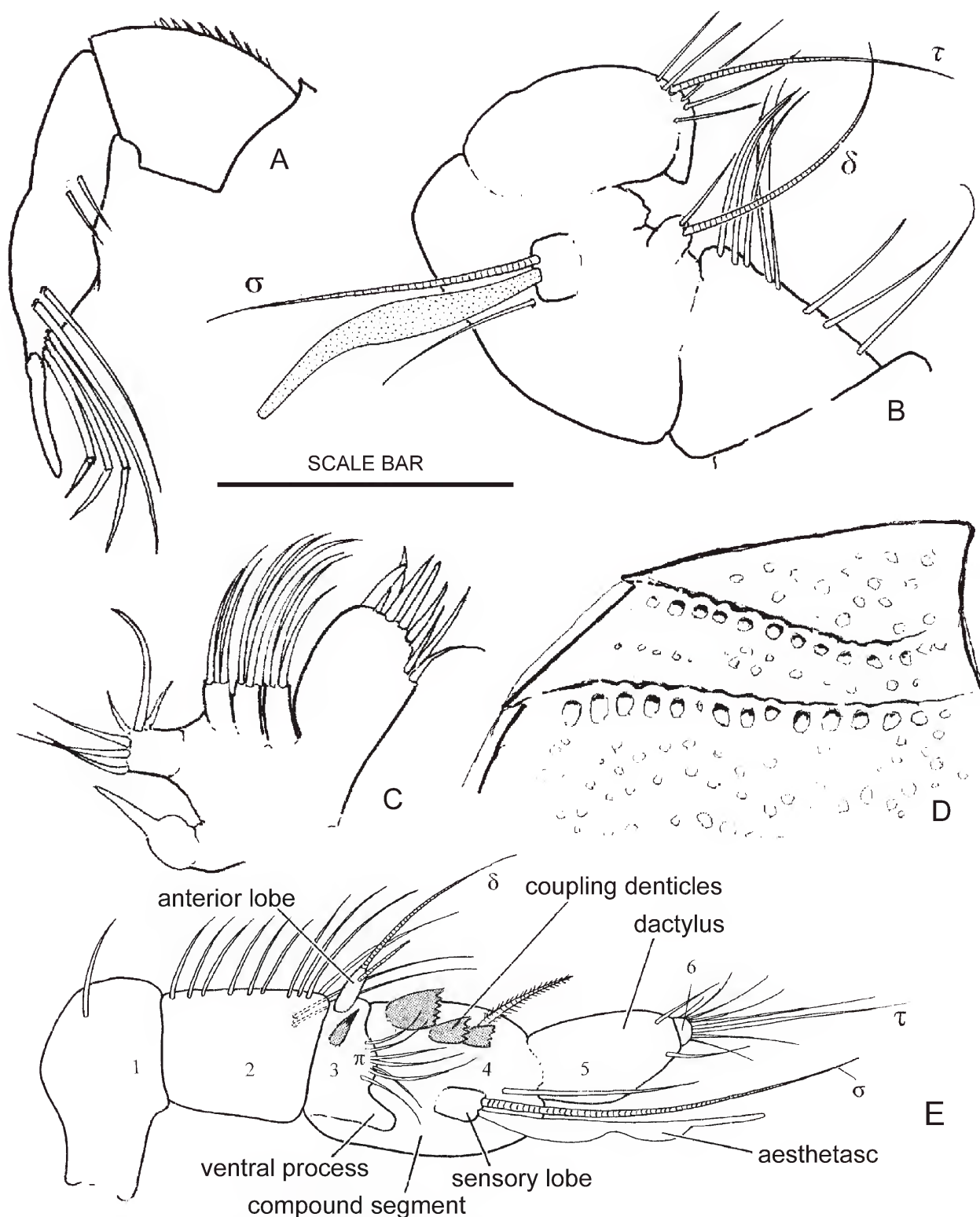


Figure 29. *Acutiramus iwasakii* sp. nov. Male: (A) antenna endopod; (C) maxillule; (D) ridges and pits on left shoulder. *Acutiramus cumulus* sp. nov. male: (B) antennule setae; (E) diagram showing terminology used in description of male antennule. Scale bar: A, B, C = 0.05 mm. D = 0.06 mm.

Both species are heavily burdened with suctorian protozoans round their perimeter (compare with Fig. 28A).

*Porcellidium tapui* described by Hicks & Webber, 1983 does not fit the diagnosis for *Porcellidium*, but fits the diagnosis for *Acutiramus* and should be moved to that genus as *A. tapui* (Hicks & Webber, 1983). *A. tapui* displays a

degree of variability in morphology and measurements that is unknown among algal living species, Hicks & Webber (1983). The question arises whether *A. cumulus* may be just an extreme form of *A. tapui*. There are some similarities between the two animals, but there are also significant differences as shown in Table 2.

**Table 2.** Differences between Australian and New Zealand animals.

<i>Acutiramus cumulus</i>	<i>Acutiramus tapui</i>
Females ♀♀	
1 Total length 0.78 mm.	Total length 0.69 mm.
2 Conspicuous bulge above rostrum.	Not mentioned.
3 Metasome segment 3 with reduced epimeral lobe that partly covers baseoendopod of P5.	Reduced epimeral lobe not shown, baseoendopod of P5 fully exposed.
4 Border setules on genital double-somite short, all same length.	Border setules of posterior lobe very long (three times longer than on anterior lobe).
5 Caudal ramus rhomboid (parallel sides).	Caudal ramus “sub-rectangular”, tapers posteriorly.
6 T1 and γ setae deeply recessed.	T1 and γ only slightly recessed.
7 T2, T3 and T4 bunched together at apex. across medial half of posterior edge.	T2, T3, and T4 not bunched together, spaced evenly
8 α and β setae wide apart (27% of ramus length).	α and β setae closer together (17% of ramus length).
9 Dorsal surface of ramus covered with conspicuous ridges.	Reticulate pattern only recorded on distal part of ramus at 3 sampling locations.
10 Seta on segment 1 of P4 endopod plain.	Seta on segment 1 of P4 plumose.
Males ♂♂	
11 Sensory lobe of male antennule without blade-like appendage.	Blade-like (acuminate) appendage present on sensory lobe (morph 1).
12 Truncated anterior border of male cephalosome broad with angular shoulders and bulge in midline.	Anterior border not as broad, without angular shoulders.
13 α and β setae on male caudal ramus not close (28% of caudal length apart).	α and β setae on male caudal ramus close (20% of ramus length apart).
14 α and β setae on male caudal ramus short (length < ½ width of ramus).	α and β setae on male caudal ramus long (α and β setae ≥ than width of ramus).
15 Male T1 and γ setae recessed from posterior border.	Male T1 and γ not recessed.
16 Male P5 trapezoid, apical angle 47°	Male P5 “sub-rectangular”, apical angle 60°

Note. It is considered that these differences justify naming the Australian and New Zealand animals as distinct species.

**Genus *Clavigofera***  
**Harris & Iwasaki, 1996**

*Clavigofera* Harris & Iwasaki, 1996: 200.—Bodin, 1997: 67; Walker-Smith, 2001: 655; Wells, 2007:80.  
*Porcellidium*.—Pesta, 1935: 377; Lang, 1948: 425; Humes & Geleman, 1962: 311; Wells, 1967; Marques, 1977: 1057; Hicks, 1982: 64.

**Type species.** *Clavigofera pacifica* Harris & Iwasaki, 1996: 201–204, figs. 1–2.

**Diagnosis.** Male antennule without denticle on segment 3, segment 4 with two denticles (never brush-pad or denticulate pad), segment 6 distinct (not fused with segment 5); anterior lobe of female genital double-somite with lateral striations (rugosities) on ventral surface (Fig. 30B); female caudal ramus rectangular, widens slightly posteriorly, terminal setae large, pinnately clavate, evenly spaced across posterior

border (Fig. 30C), T1 same size and shape as T2–T4, not recessed; cephalosome with hyaline border, marginal glands open dorsal to border, cuticular honeycomb absent; female genital double-somite narrow, pointed posteriorly; maxillule endopod with six setae; coxal lobes of maxillipeds touch in midline, basis with fimbriate process; no ventral expansion to female P5 exopod, P5s extend to or beyond posterior extremity of genital double-somite, do not touch posteriorly; male P5 trapezoid with one lateral and five terminal setae; spermatophore elongate, ephemeral on female.

**Species composition.** *Clavigofera clavigera* (Pesta, 1935); *C. echinophila* (Humes & Geleman, 1962); *C. laurencia* (Hicks, 1982); *C. ulva* (Hicks, 1982); *C. pacifica* Harris & Iwasaki, 1996.

The genus is widely distributed and occurs in the southern Atlantic Ocean (St. Helena), Indian Ocean (South Africa, Mozambique, and Madagascar), northern Pacific Ocean (Japan, Hawaii) and southern Pacific Ocean (Australia).

**Table 3.** Values of Hicks’ index for α seta on caudal ramus of *Cladofera* species.

species	α% (mean)	range (%)	number in sample	locality
<i>Clavigofera pacifica</i>	52.3	50–55.5	27	Iwate Prefecture, Japan
<i>C. pacifica</i>	52.7	51–55	23	NSW, Australia
<i>C. echinophila</i> *	52.3	49.5–55.5	8	Madagascar
<i>C. laurencia</i> *	57.6	56.3–60	10	South Africa
<i>C. ulva</i> *	62.5	59–65.5	10	South Africa
<i>C. clavigera</i> *	67.35	—	1	Hawaii

\* data from Hicks (1982).

Key to the species of *Clavigofera*

- 1       $\delta$  seta on male antennule “whip-like” ( $>$  than length of antennule), length of female  $> 0.75$  mm ..... *Clavigofera ulva* (Hicks, 1982)
- $\delta$  seta on male antennule not long ( $<$  length of antennule). Length of female  $< 0.75$  mm ..... 2
- 2      Length of female  $\leq 0.5$  mm, Hicks’ index for  $\alpha$  seta  $> 65\%$  ..... *Clavigofera clavigera* (Pesta, 1935)
- Length of female  $> 0.5$  mm, but  $< 0.75$  mm, Hicks’ index for  $\alpha$  seta  $< 60\%$  ..... 3
- 3       $\alpha$ ,  $\beta$  and  $\gamma$  setae of male =  $\frac{3}{4}$  length of caudal ramus. Animals associated with sea urchins ..... *Clavigofera echinophila* (Humes & Gelerman, 1962)
- $\alpha$ ,  $\beta$  and  $\gamma$  setae less than  $\frac{2}{3}$  length of male caudal ramus. Animals found on seaweed ..... 4
- 4      Hicks’ index for  $\alpha$  seta on female caudal ramus  $> 55\%$ . Length of striated area  $< \frac{1}{4}$  length of genital double-somite ..... *Clavigofera laurencia* (Hicks, 1982)
- Hicks’ index for  $\alpha$  seta on female caudal ramus  $< 55\%$ . Length of striated area =  $\frac{1}{3}$  length of genital double-somite ..... *Clavigofera pacifica* Harris & Iwasaki, 1996

**Remarks.** *Clavigofera pacifica* was first described from Iwate Prefecture, Honshu, Japan, Harris & Iwasaki (1996). Hicks (1982) placed emphasis on the position of the  $\alpha$  seta on the female caudal ramus to separate species from S. Africa, Madagascar and Hawaii in his “*clavigerum* complex” (see Table 3 above). Harris & Iwasaki (1996) raised the “*clavigerum* complex” to generic status on the grounds that the striations on the genital double-segment and shape of the terminal setae on the caudal rami are apomorphic characters. Although the species look very similar, biometric differences support their separation into distinct species.

Based on ecological differences, statistical analysis of size and position of the  $\alpha$  seta, Hicks (1982) considered *C. echinophila*, *C. laurencia* and *C. Ulva* to be three distinct species. Corresponding analysis shows that there is a highly significant difference in size and position of the  $\alpha$  seta between *C. laurencia* and *C. pacifica*. *Clavigofera echinophila*, however, has the same value for  $\alpha$  seta as *C. pacifica*, but morphological and ecological differences clearly show the two species are distinct, (*C. pacifica* lives on seaweed, *C. echinophila* lives in association with a sea urchin, Humes & Gelerman (1962).

**Etymology.** Pesta (1935) described the terminal setae on the caudal rami as “club-shaped” (keulenförmiger Gestalt). The generic name is derived from this, (L. *clava* = club + *fero* = to bear, carry).

*Clavigofera pacifica* Harris & Iwasaki, 1996

Figs 30–33

*Clavigofera pacifica* Harris & Iwasaki, 1996: 201, 204, figs. 1, 2.—Bodin, 1997: 67; Wells, 2007: 80.

**Type material.** Type locality: Kadanohama Bay, Ofunato, Iwate Prefecture, Japan. Holotype (female) NSMT-Cr 11950, allotype NSMT-Cr 11951 deposited in the National Museum of Natural Sciences, Tokyo, Japan.

Australian specimens from NSW deposited at the AM, Sydney, P89053, 20 ♀♀, 10 ♂♂, 8 ♂♂ coupled with juvenile female *ex Lobophora variegata*, Shelly Beach, Cronulla, Sydney, 34°03'S 151°11'E) V. A. Harris, 1974. Australian specimens deposited at NHM, London.

**Diagnosis.** Ventral surface of cephalosome with wrinkles parallel to edge, hyaline border with striations parallel to edge; lateral striations on female genital double-somite 10% of animal’s length; Hicks index for  $\alpha$  on female caudal ramus = 52%;  $\alpha$  and  $\beta$  setae on male caudal ramus short ( $\frac{1}{3}$  length of ramus);  $\delta$  seta on segment 3 of male antennule about same length as segment 2; setules absent from anterior lobe of mandible; antenna endopod segment 2 without extensive area of setules; no row of setules on lateral surface of maxilliped basis.

**Biometric data.** Data for Australian specimens, (values for Japanese specimens within square brackets).

**Females** (N = 29 [27]): maximum length ( $L_{\max}$ ) mean 0.59 mm [0.61 mm], body length ( $L_{\text{urs}}$ ) mean 0.57 mm [0.58], range 0.53–0.58 mm; cephalosome width (W) mean 0.35 mm [0.39 mm]; rostrum width (R) 0.060 mm [0.065 mm]; genital double-somite width 0.22 mm; caudal ramus length 0.16 mm, width (max) 0.065 mm.

Ratios: ( $L_{\max}$ )/W 1.65, ( $L_{\text{urs}}$ )/W 1.52; caudal ramus l/w 2.4 [2.2], Hicks index for  $\alpha$  52% [52%]; number of eggs carried by female 6 [6].

**Males** (N = 14 [16]): maximum length ( $L_{\max}$ ) mean 0.44 mm [0.42 mm], range 0.40–0.47 mm, body length ( $L_{\text{urs}}$ )



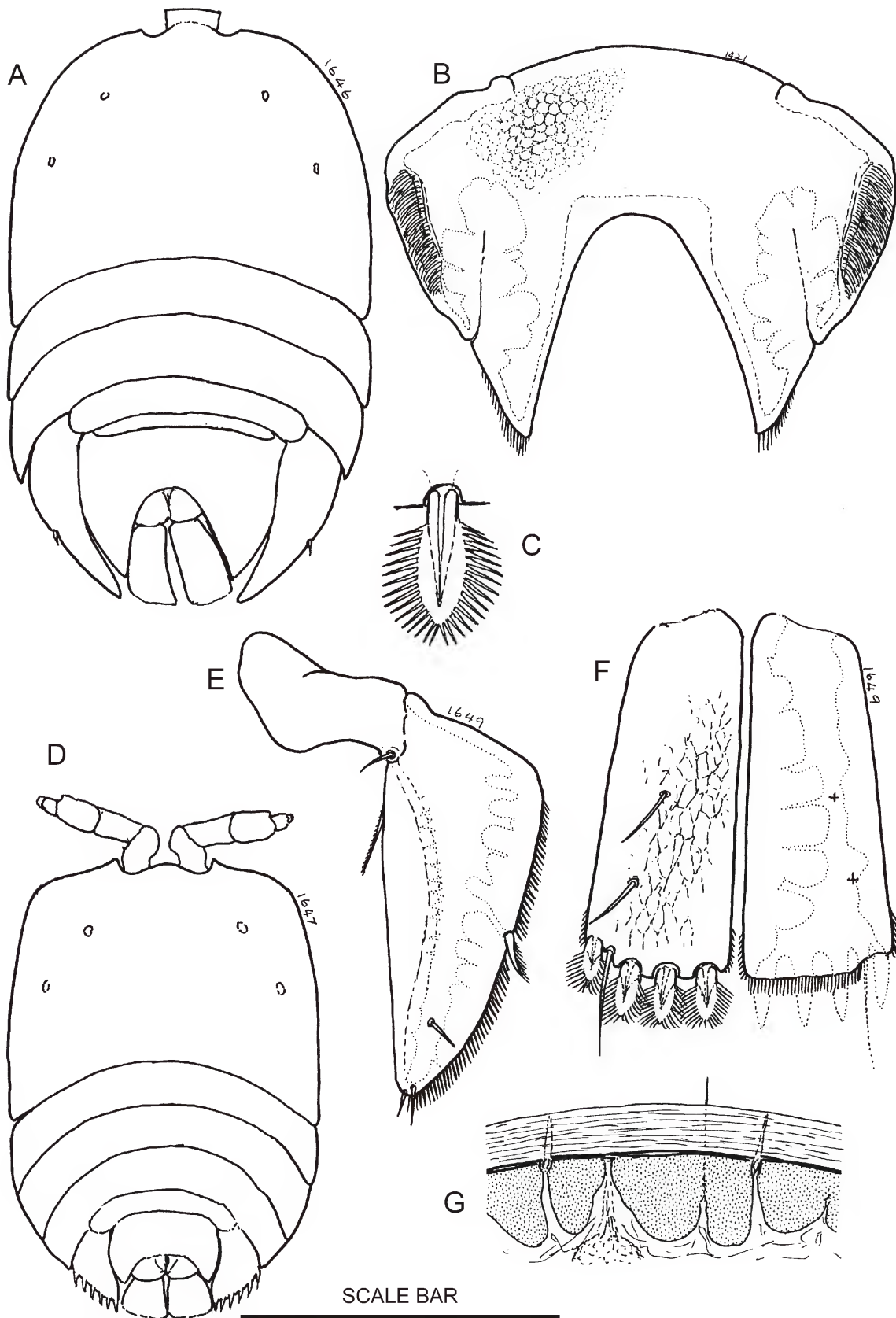


Figure 30. *Clavigofera pacifica* Harris & Iwasaki, 1996, (Australian specimens). Female: (A) adult; (B) genital double-somite; (C) pinnate clavate seta from caudal ramus; (E) P5 (dorsal); (F) caudal rami (dorsal left, ventral right); (G) hyaline border with parallel striations. Male: (D) adult. Scale bar: A, D = 0.32 mm, B = 0.18 mm. E = 0.15 mm, F = 0.14 mm, G = 0.06 mm. (C not to scale).

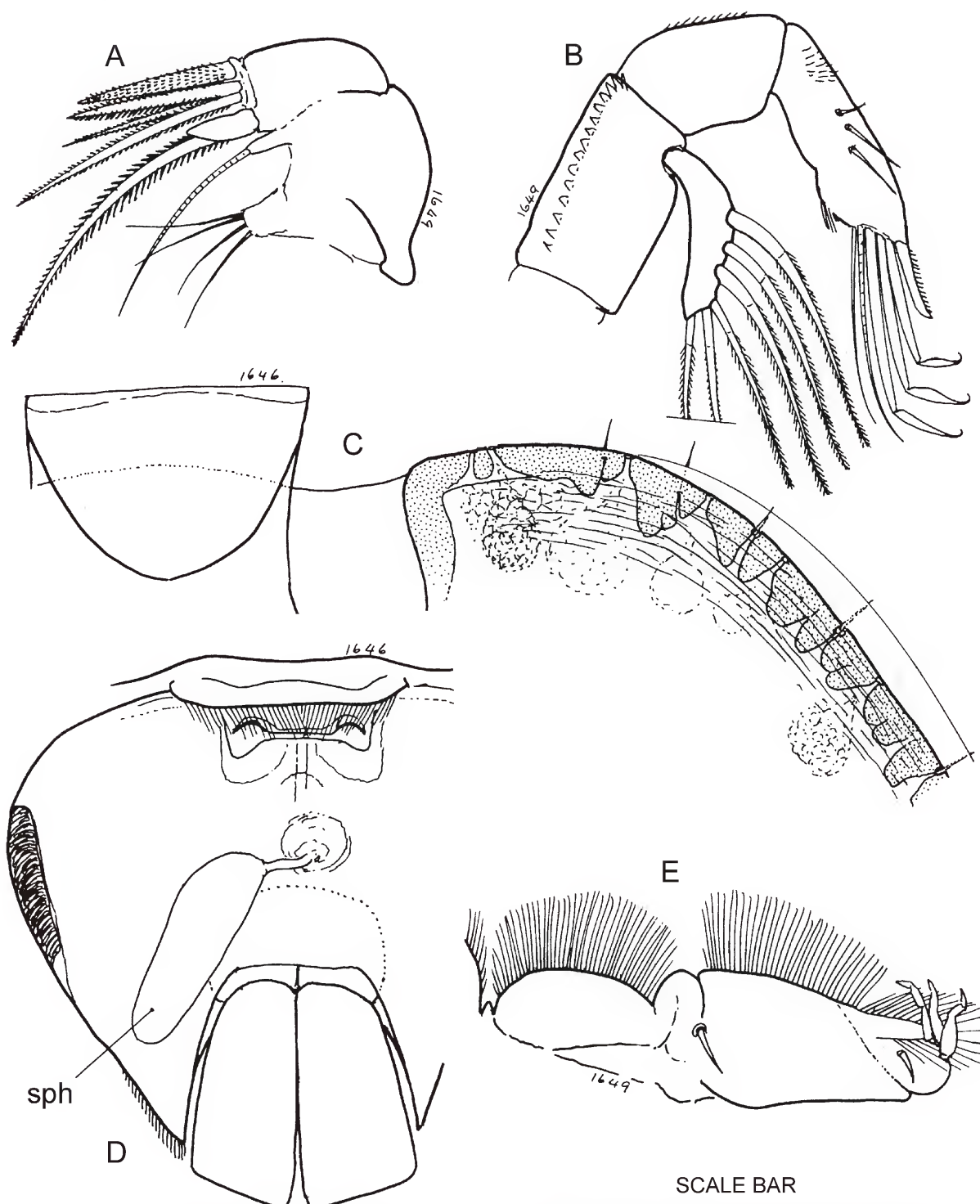


Figure 31. *Clavigofera pacifica* Harris & Iwasaki, 1996. Female: (A) maxilla; (B) antenna; (C) rostrum and “shoulder” (ventral); (D) genital double-somite with spermatophore attached (ventral view); (E) maxilliped. Scale bar: A, B, E = 0.07 mm. C = 0.04. D = 0.18 mm.

mean 0.39 mm [0.38 mm]; cephalosome width (W) mean 0.32 mm [0.31 mm]; antennule length (N = 6) 0.123 mm; spermatophore length 0.08 mm.

Ratios: ( $L_{urs}$ )/W 1.22; antennule 28% of ( $L_{urs}$ ) [measurements of male antennule segments made on two paratype specimen from Japan fall within the range of animals from Australia], segment 2 37%, segment 3+4 36%, dactylus 17%, aesthetasc 68% of antennule length,  $\delta$  seta = length of segment

2, spermatophore 21% of ( $L_{urs}$ ).

**Description.** *Adult females* (Fig. 30A): colour pale yellow or colourless. Anterior of cephalosome slightly truncated, rostrum very narrow (18% of cephalosome width). Sides of body outline almost parallel. Hyaline border with striations parallel to edge (Fig. 30G), 10  $\mu$ m wide, dorsal pits conspicuous, 5–6  $\mu$ m. Ventral surface of cephalosome

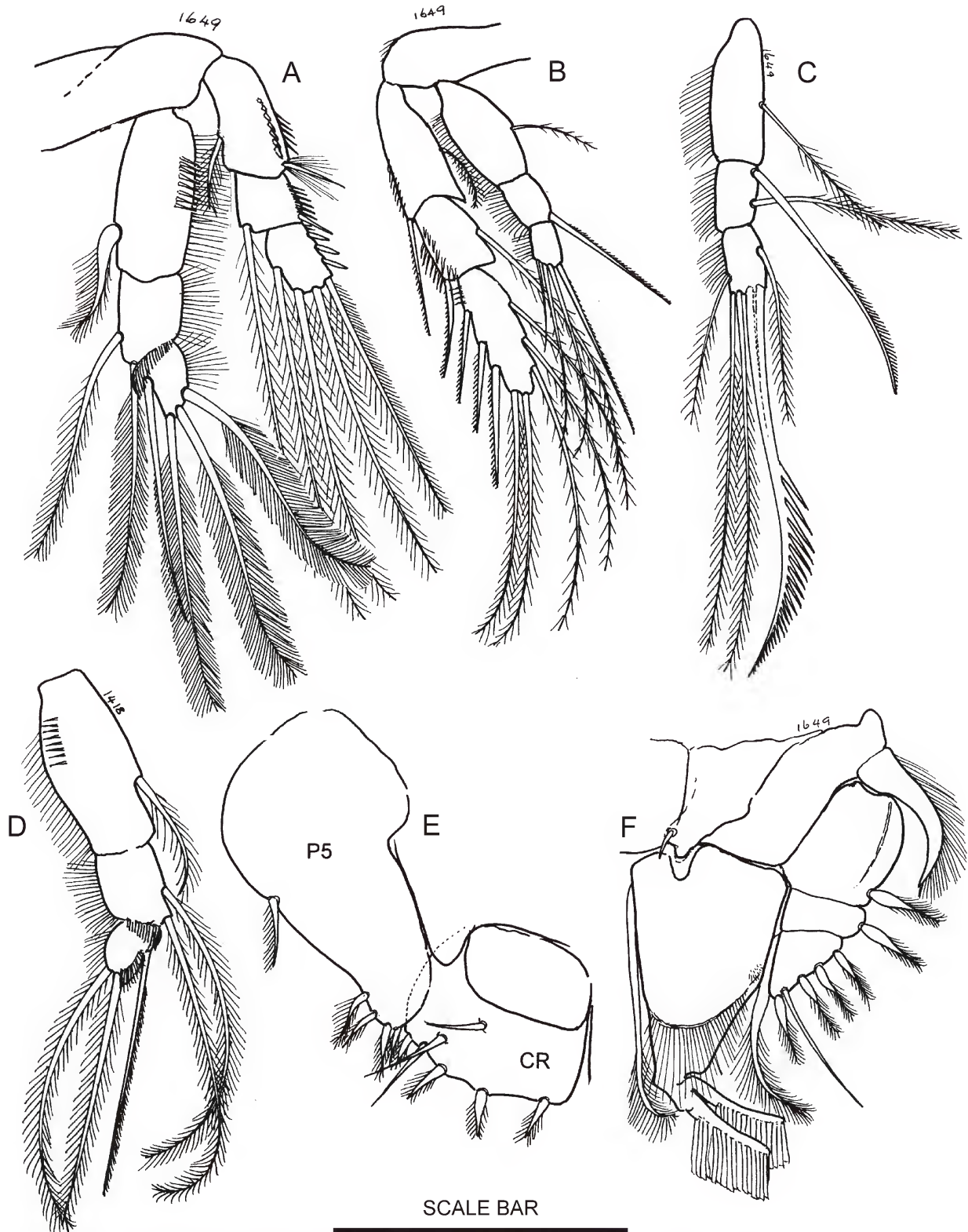


Figure 32. *Clavigofera pacifica* Harris & Iwasaki, 1996. Female: (A) P2; (B) P4; (C) P3 endopod; (E) P5 and caudal ramus of stage V female copepodid; (F) P1. Male: (D) P2 endopod. Scale bar: A, D = 0.1 mm. B, C, E = 0.08 mm. F = 0.09 mm.

with wrinkled cuticle parallel to border (Fig. 31C). Lateral band of striations (striated rugose band) on ventral surface of genital double-somite anterior lobe 33% of somite length, dorsal surface of genital double-somite pitted. Notch and broad scar indicate boundary between anterior and posterior

lobes (Fig. 30B), posterior lobe narrow, straight sided, acutely pointed posteriorly, bordered with fine setules. Posterior arch deep, encloses almost  $\frac{3}{4}$  of caudal furca. Sternal sclerite of metasome segment 4 fimbriate on posterior edge (Fig. 31D). Caudal rami rectangular, widen posteriorly (Fig. 30F),



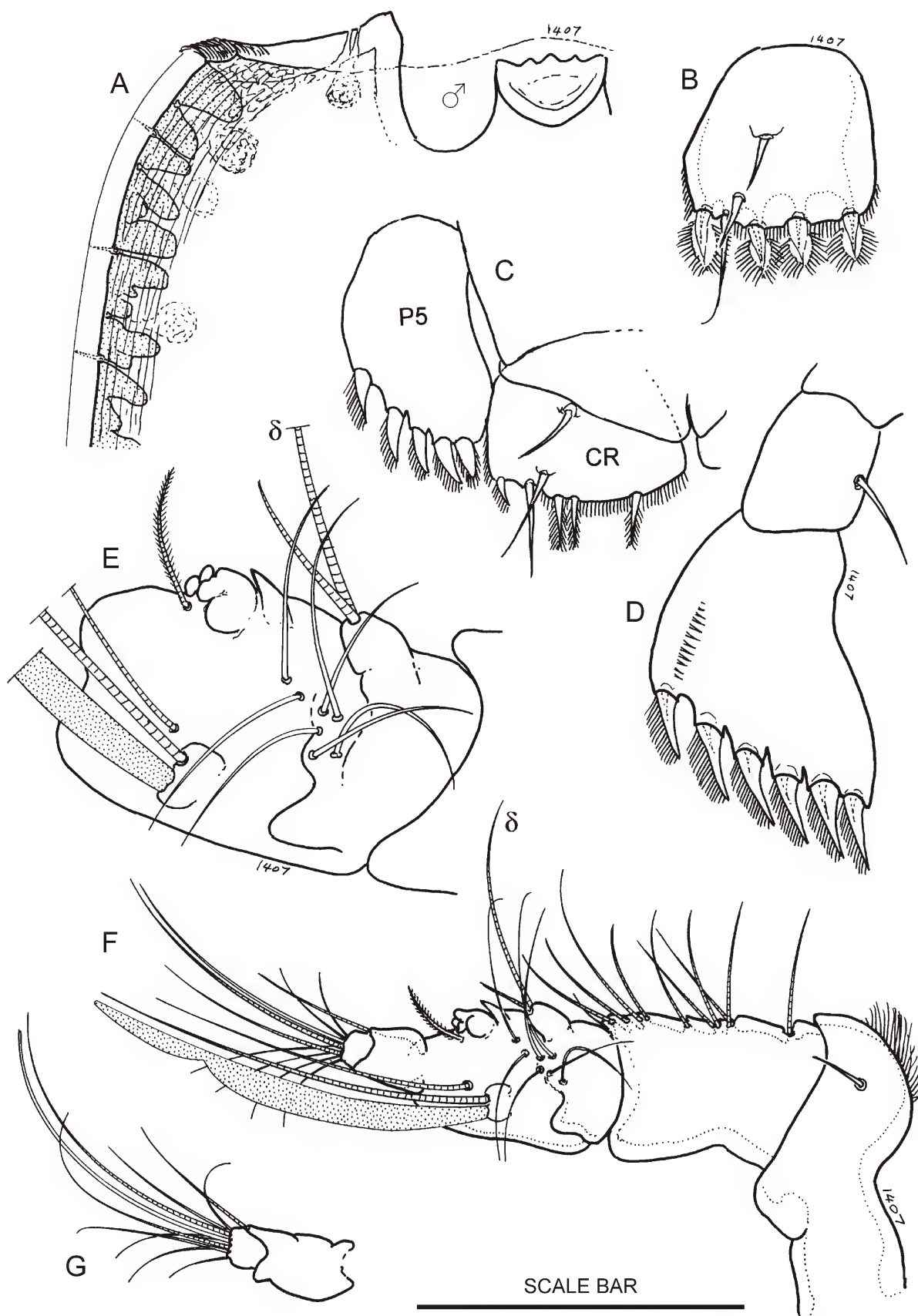


Figure 33. *Clavigofera pacifica* Harris & Iwasaki, 1996. Male: (A) rostrum and "shoulder" (ventral); (B) left caudal ramus; (C) P5 and caudal ramus of stage V male copepodid; (D) P5; (E, F, G) antennule (E, detail of segment 4; G, dactylus). Scale bar: A, C, D = 0.07 mm. B, F, G = 0.08 mm. E = 0.04 mm.

posterior border slightly convex with terminal fringe of setules. Terminal setae T1–T4 large, pinnately clavate (Fig. 30C), evenly spaced along posterior edge [terminal setae of copepodids are not pinnately clavate],  $\alpha$  seta about half way down ramus. Structure and setation of mouthparts and ambulatory limbs typical of family. Segment 2 of antenna endopod with a few surface setules, no extensive rows of setules (Fig. 31B). Mandibular palp without setules on anterior lobe. Maxillule with single bulbous seta on exopod. Seta on distal endite of maxilla plain, not comb-like (Fig. 31A). Maxilliped without lateral row of surface setules on basis (Fig. 31E). Very small patch of denticles at lateral end of fimbriate crescent on P1 endopod (Fig. 32F). Serrulate spinous terminal seta on P2 endopod  $\frac{3}{4}$  length of endopod (Fig. 31A). Serrulate spinous seta on segment 2 of P3 endopod shorter than endopod (0.85:1), large serrate spinous seta on segment 3 of endopod much longer than endopod (1.5:1) (Fig. 32C). Seta on segment 2 of P4 endopod and first internal seta on segment 3 finely serrulate, spinous (Fig. 32B). Exopod of P5 lanceolate, dorsal surface pitted, one dorsal seta plus sub-apical and smaller apical seta (Fig. 30E), apex of P5s reach beyond posterior extremity of genital double-somite but do not touch one another. Females carry six eggs.

**Adult males** (Fig. 30D). Colour, hyaline border, dorsal pits and wrinkled ventral edge of cephalosome as described for female. Cephalosome truncated, anterior edge turned ventrally, lateral angle of antennule socket prominent, shoulders sharply rounded (Fig. 33A). Caudal rami quadrate ( $l/w = 1$ ) with lateral edge convex, dorsal surface pitted,  $\alpha$  and  $\beta$  setae short (less than half length of ramus), terminal setae T1–T4 pinnately clavate, equal in size and equally spaced (Fig. 33B). Limbs as for female except for the following. Antennule held in characteristic posture when not folded ventrally (Figs 30D, 33F), segment 2 as long as segment 4 + dactylus, segment 3 with very short ventral process,  $\delta$  seta short (= length of segment 2), aesthetasc nearly twice length of segment 2, coupling denticles on segment 4 very small, proximal pointed, distal rounded, dactylus short with segments 5 and 6 distinct ( $\frac{1}{2}$  length of segment 2) (Figs 33E, F, G). Endopod of P2 with two plumose and one serrulate spinous seta on segment 3 (Fig. 32D). Spermatophore about  $\frac{1}{5}$  length of animal.

**Remarks.** Detailed descriptions of *Clavigofera clavigera*, *C. laurencia* and *C. ulva* that would confirm their validity were not given. A full description of these species is needed to justify use of Hicks' index to separate them.

Stage IV and V male and female copepodides have slender pinnate terminal setae on their caudal rami (Figs 32E, 33C). The characteristic pinnately clavate terminal setae of adults appear at metamorphosis.

**Distribution.** *Clavigofera pacifica* is widely distributed on the coasts of Japan. Australian specimens have been collected from the mid and northern coast of NSW.

The species has been recorded as abundant on *Lobophora variegata* at the following localities: Broulee rock platform (35°52'S 150°71'E) 47 ♀♀, 22 ♂♂, 6 coupled ♂♂; Shelly Beach, Cronulla, Sydney (34°03'S 151°11'E) 103 ♀♀, 85 ♂♂, 41 coupled ♂♂; Arrawarra Headland (30°03'S 155°02'E) 122 ♀♀, 70 ♂♂, 74 coupled ♂♂, V. A. Harris 1974, 1976, 1982. The species has been collected from a number of other seaweeds in smaller numbers. On *Caulerpa* sp., at Broulee, and Ballina (28°52'S, 153°36'E) also on *Gelidium* sp., at Nambucca Heads (30°39'S 153°01'E) V. A. Harris 1982.

## Discussion

Three of the new species described here are of particular interest because they belong to genera already known from Japan and Korea. They are clearly defined by apomorphic character states that exclude them from other genera including *Porcellidium* (see Harris, 2014).

The genus *Kushia*, characterized by an anterior comb on segment 3 of male antennule, has three species in Japan. It is represented in NSW, Australia by *Kushia spathoides* sp. nov. A second genus, *Kensakia*, characterized by a unique brush-pad on segment 4 of the male antennule, has two species in Japan and Korea, and one each from Sri Lanka and Malaysia. It is represented in Queensland by *Kensakia australis* sp. nov. A new genus, *Synurus* has been erected to accommodate the third species, *Synurus ctenocheirus* sp. nov., which shows two features that are considered autapomorphic (i.e., fusion of male P5 baseoendopod with metasome segment 4 and genital somite, and atrophy or loss of five terminal setae from the male P5 limb). This species was collected from the Great Barrier Reef at Cairns, Queensland, but it has also been found on Okinawa Island, Japan (specimens in Yuka Sasaki's personal collection examined by author. Sasaki confirms that measurements of her animals fall within the range given in text above). The only other species known to occur in both Japanese and Australian waters is *Clavigofera pacifica* Harris & Iwasaki, 1996 and reported here from NSW for the first time.

**The male antennule in porcellidiid taxonomy.** In the study of Australian and Japanese species it was found that the female antennule is remarkably uniform in its structure and setation throughout the family and is of little taxonomic importance. On the other hand, the highly modified antennule of adult male animals shows an extremely wide range of structure that provides more useful taxonomic characters than any other part of the body. Of 60 species for which the detailed structure of the male antennule is known, segment shape, type and number of setae, shape and position of chitinous tooth-like structures (coupling denticles), was found to be specific for each species. Consequently, the identity of any male animal can be determined with certainty if the male antennule of the species has been described. In contrast, not all female animals can be identified with certainty from female characters alone. A detailed description of the male animal becomes an absolute requirement for a valid description of any porcellidiid.

In the Porcellidiidae the antennule of both male and female animals is reduced to six morphological segments, but the partial fusion of segments 3 and 4 and (in most species) segments 5 and 6 of male animals gives the impression that there are only four or five segments (Fig. 29E). Segment 3 cannot be seen from dorsal view, but in ventral view it appears as a separate structure bearing the  $\delta$  and  $\delta'$  setae on an anterior process plus a group of five to seven  $\pi$  setae, and (in some species) a single coupling denticle. Hicks & Webber (1983) describe this segment as a "lappet" of segment 2, but its setation shows it to be segment 3. In the majority of species segments 5 and 6 are fused (referred to as the dactylus), but in others species segment 6 is distinct (Fig. 33G).

The male antennule is subchirocer with the neocopepodan articulation between segments 4 and 5, Huys & Boxshall (1991). It is prehensile with segment 4 greatly enlarged

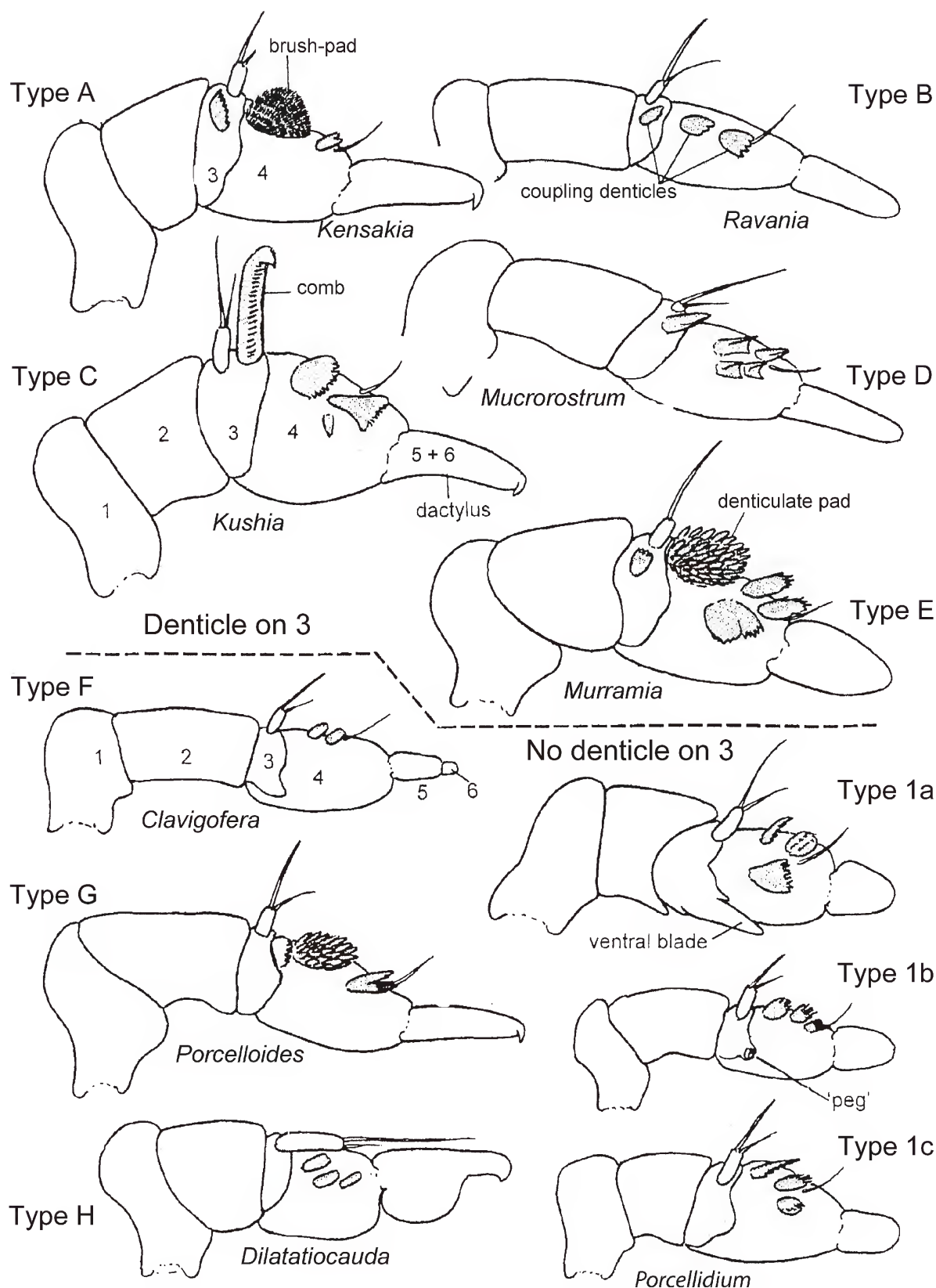


Figure 34. Characteristic arrangement of male coupling denticles in certain genera (diagrammatic, see text). Type A, *Kensakia*; Type B, *Ravania*; Type C, *Kushia*; Type D, *Mucrorostrum*; Type E, *Murramia*; Type F, *Clavigofera*; Type G, *Porcelloides*; Type H, *Dilatatiocauda*; Types 1a, 1b, 1c, *Porcellidium*.



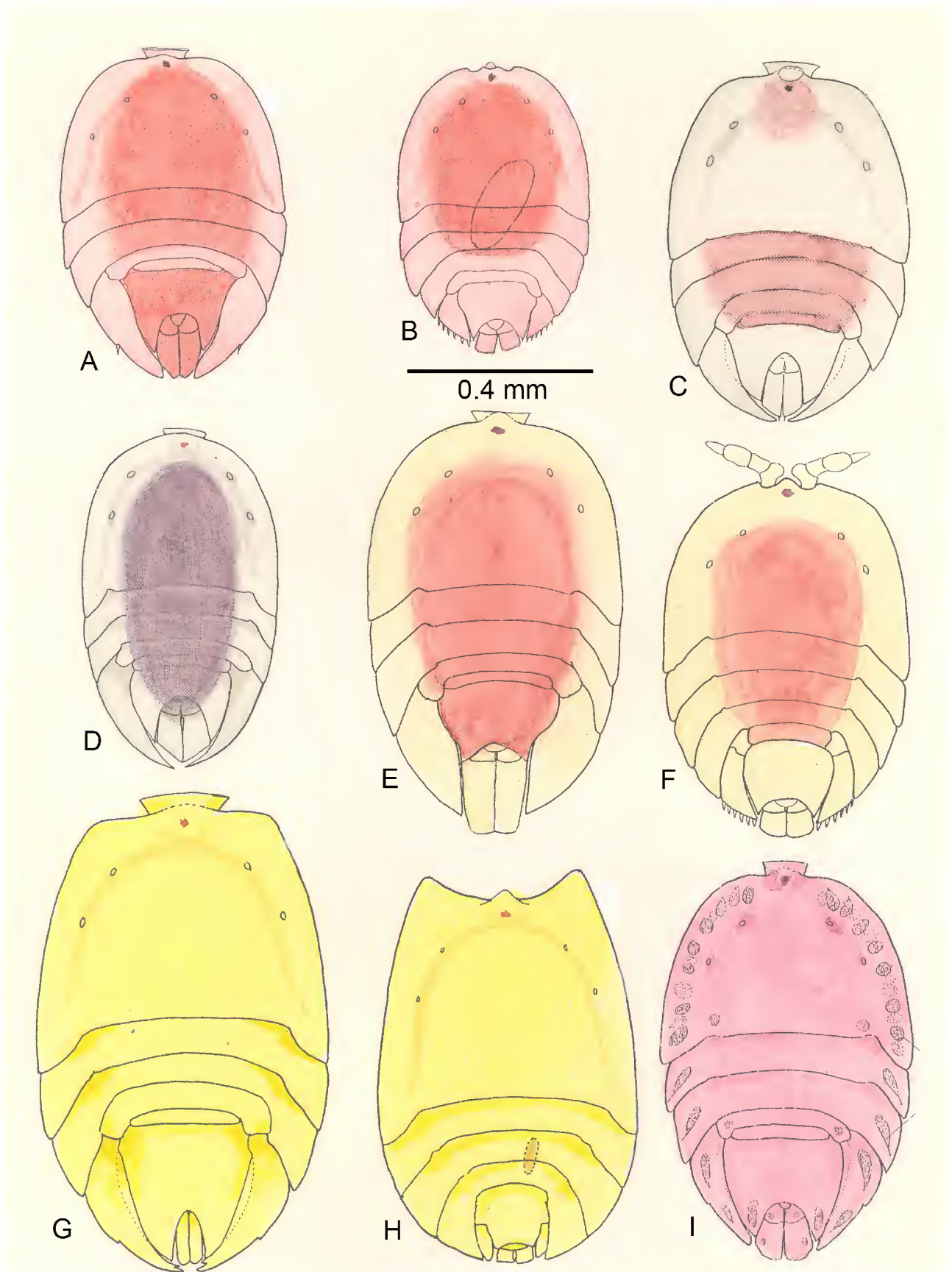


Plate 1. (A) *Ravania wellsi* sp. nov., female; (B) male. (C) *Acutiramus bipunctatus* sp. nov., female. (D) *Kensakia australis* sp. nov., female. (E) *Ravania doliocauda* sp. nov., female; (F) male. (G) *Synurus ctenocheirus* sp. nov., female; (H) male. (I) *Kushia spathoides* sp. nov., female. A–I Australian species. Scale bar: 0.4 mm.

to accommodate the massive adductor muscle that closes the finger-like dactylus against the ventral side of segment 4. This enables the male to grip the posterior region of a juvenile female during mate guarding behaviour. The number and position of setae on the antennule is more or less constant throughout the family, but setae may differ from species to species in type (plain, annulate, plumulose) and length (compare Figs 28G and 29B). The chitinous coupling denticles are not modified setae, they appear *de novo* at the final moult or metamorphosis of the male from stage V copepodid to adult, Harris (1994). They are only found on the ventral side of segments 3 and 4. Many species do not have a denticle on segment 3, but when it is present, there is never more than one. Segment 4, however, always has one to five denticles. The shape of these denticles varies widely, from simple thorn-like structures to complex brush-like pads, clusters of denticles (denticulate pads), flat plates with plain or serrated edge, comb-like denticles, plain tooth-like denticles and even small balloon-like structures (Fig. 12G).

It is assumed the coupling denticles enable the male to grip the female copepodid more effectively by increasing friction. There is no evidence for a “locking mechanism” as there is no corresponding depressions on the juvenile’s P5 or posterior region of the body into which the denticles could fit. Apart from differences in size and shape between juvenile stages, there is surprisingly little variation in shape or structure of the abdominal region between species of female copepodids. This suggests the variability of the male’s coupling denticles is not connected with a species isolating mechanism or a mechanism whereby adult males can distinguish between male and female copepodids.

When the male antennule is compared between species, a clear correlation can be seen between certain arrangements of denticles (number and shape) and particular genera. The clearest example of this is seen in the genus *Kushia* with four described species. The genus is defined by the unique ventral expansion on the female P5 (Fig. 16E), but the characteristic anterior comb on segment 3 of the male antennule is equally unique (Fig. 18E, F); both can be regarded as apomorphic characters. Similarly, the brush-pad only found on segment 4 of all species of *Kensakia* should be considered autapomorphic. A remarkable similarity in the arrangement of denticles can be seen in species belonging to other genera. In Fig. 34 the typical arrangement of denticles is shown diagrammatically for certain porcellidiid genera. The arrangement of denticles can be divided into two groups: those with one denticle (or comb) on segment 3 and those without a denticle on segment 3. In each group segment 4 may have two, three, four or five denticles. In the first group *Kensakia* (type A) and *Rvania* (type B) have only two denticles. *Kushia* (type C) has three denticles of characteristic shape. *Mucrorostrum* (type D) and *Murramia* (type E) both have four denticles, but the shape of the denticles is very different in the two genera (*Murramia* is unique in lacking the  $\delta'$  seta). The second group, without a denticle on segment 3, is less clearly defined but *Clavigofera* (type F) appears to have two denticles on segment 4 (the antennule has not been described for all the known species). *Porcelloides* has three characteristically shaped denticles (type G). *Porcellidium* (type Ia, Ib, Ic) also has three denticles but their shape is much more variable. This genus may have a ventral process to segment 3 in the shape of a “blade” or “peg”, but this is not unique to *Porcellidium* for it is found in *Tectacingulum*,

*Acutiramus*, *Synurus* and *Dilatatiocauda*. The latter genus shows another unusual feature, the anterior process carrying  $\delta$  and  $\delta'$  setae lies parallel to the axis of the antennule (horizontal); in most other species the process and  $\delta$  seta project forwards.

Because the configuration of the setae and denticles is unique for each species, male animals have been chosen as the holotype for each of the new species described above.

ACKNOWLEDGMENT. I am grateful to Yuka (Tadasugi) Sasaki for allowing me to examine her extensive collection of Porcellidiidae from Japan.

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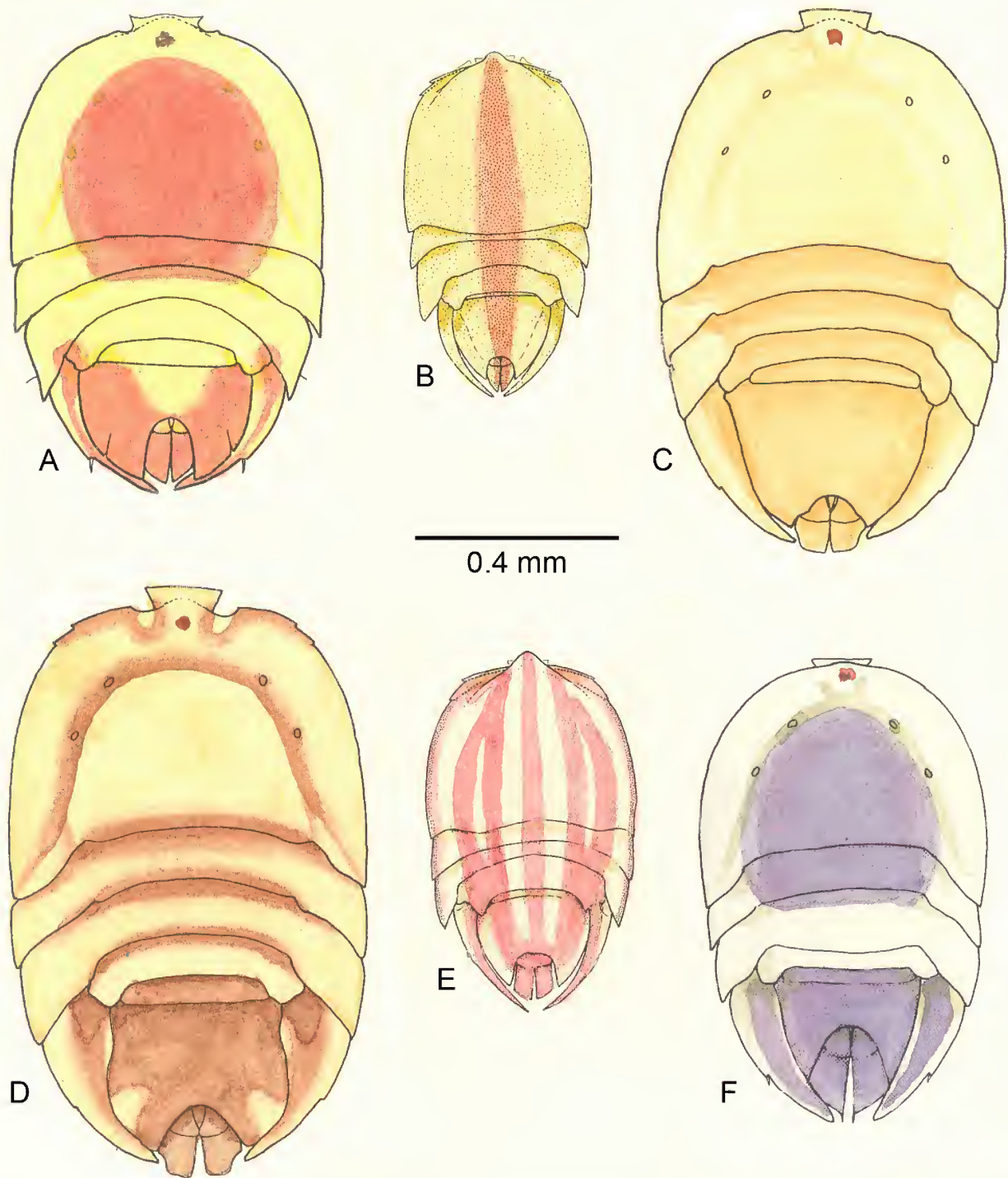


Plate 2. (A) *Acutiramus sesquimaculatus* (Harris, 1994), female, Australia. (B) *Acutiramus rufolineatus* Harris & Robertson, 1994, female, Australia. (C) *Kushia igaguria* Harris & Iwasaki, 1996, female, Japan. (D) *Kushia zosterophila* Harris & Iwasaki, 1996, female, Japan. (E) *Acutiramus quinquelineatus* Harris & Robertson, 1994, female, Australia. (F) *Kensakia acuta* (Kim & Kim, 1997), female, Korea and Japan. Scale bar: 0.4 mm.



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Manuscript received 7 September 2012, revised 6 January 2014 and accepted 22 January 2014.

Associate Editor: Dr Shane T. Ahyong.